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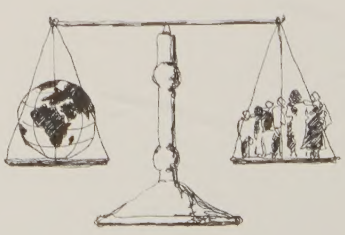

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Targeting perennial vegetation in agricultural landscapes for enhancing ecosystem services

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Abstract

Over the past century, agricultural landscapes worldwide have increasingly been managed for the primary purpose of producing food, while other diverse ecosystem services potentially available from these landscapes have often been undervalued and diminished. The incorporation of relatively small amounts of perennial vegetation in strategic locations within agricultural landscapes dominated by annual crops—or perennialization—creates an opportunity for enhancing the provision of a wide range of goods and services to society, such as water purification, hydrologic regulation, pollination services, control of pest and pathogen populations, diverse food and fuel products, and greater resilience to climate change and extreme disturbances, while at the same time improving the sustainability of food production. This paper synthesizes the current scientific theory and evidence for the role of perennial plants in balancing conservation with agricultural production, focusing on the Midwestern USA as a model system, while also drawing comparisons with other climatically diverse regions of the world. Particular emphasis is given to identifying promising opportunities for advancement and critical gaps in our knowledge related to purposefully integrating perennial vegetation into agroecosystems as a management tool for maximizing multiple benefits to society.

Key words: biodiversity, ecosystem services, perennial plants, resilience, sustainable agriculture

Introduction

With the intensification of global food production, agricultural strategies have increasingly emphasized maximizing crop yields, often at the expense of other ecosystem services (ES)[1]. This has been accomplished, in part, by replacing the original native vegetation with simplified systems dominated by a single or a few crop species, and by favoring annual over perennial species. Although this trend has led to the more than doubling of global food production since the 1950s[2], maintaining these productivity levels over time demands large amounts of external inputs such as fertilizers, pesticides, irrigation and fossil fuels[3]. Concomitantly, many of the ES provided by diverse, native plant communities—including regulating (e.g., water supply and quality, climate and pest control), supporting (nutrient cycling, soil formation and pollination), and cultural (spiritual, recreation, education, medicine, etc.) services—are being lost or severely diminished[4]. As the global society increasingly confronts the consequences of these losses—acutely evidenced by expanding hypoxic zones, declining

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water quality, increased incidence of severe flooding and drought, and impoverished biodiversity—there is a growing urgency for developing multifunctional agricultural landscapes that provide diverse ES in addition to provisioning services such as food, fiber, fuel and fodder production[5–7].

One promising approach to expanding ES provided by agricultural landscapes is through 'perennialization', defined here as the strategic incorporation of diverse perennial plants as integral and purposeful components of agroecosystems to enhance ES benefits. This approach is based on the premise that the positive impacts of perennial plants can be magnified when perennials are targeted to landscape positions that yield disproportionately high ES benefits relative to the land area they occupy. Diverse perennial plant communities have been shown to enhance hydrologic regulation[8], water quality[9], carbon sequestration and storage[10], beneficial organisms for pest control and pollination[11], soil quality[12] and biological functioning[13] relative to simplified cropping systems. Perennial plants can also provide a range of provisioning services to society, including food, fiber, fuel and feed, which can contribute to diversifying production and reducing risk. The societal benefits of perennialization also include cultural and social amenities, as more diverse landscapes can positively impact aesthetic, recreational, tourism and health values within local communities[14].

Perennialization can also provide a tool for both mitigating and adapting to climate change. Climate change poses a major threat not only to agricultural productivity but also to the capacity of agricultural systems to provide diverse ES[15,16]. In recent decades, an emphasis of agronomic research has been the development of technologies for maintaining crop yields under future climates, for example, by increasing external inputs, crop breeding or genetic engineering[17–19]. However, these approaches often do not consider the importance of concomitantly sustaining the diverse ES of agricultural landscapes[20]. Increasing the amount of perennial cover in agricultural landscapes generally augments biodiversity, and more diverse ecological communities tend to have greater resilience (the ability to recover rapidly from stress), and stability (the ability to resist change or withstand stress without loss of function), relative to simplified plant communities[21]. Perennialization, by increasing biodiversity of both plants and biological organisms, provides one mechanism for enhancing agroecosystem resilience and stability of cropping systems and their associated ES under climate change[22–24]. With the frequency of extreme events such as drought, flooding, pest infestation and disease predicted to increase under future climates[25], enhanced resilience and stability will be critical for maintaining the long-term sustainability of food production systems[22,26,27].

Although multifunctionality of agricultural landscapes is not a new concept[5–7], studies documenting ES consequences when some portions of agricultural

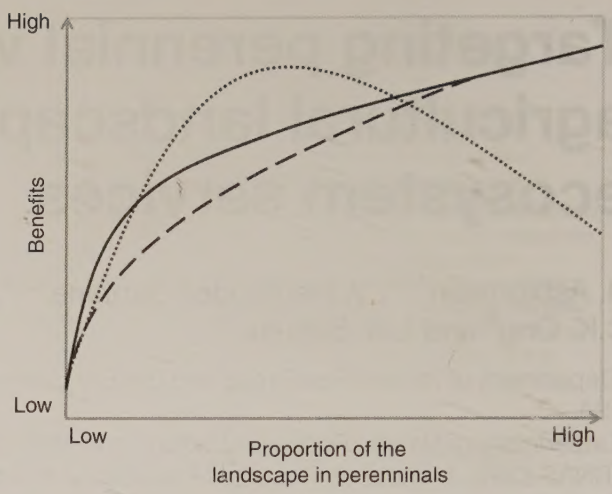

Figure 1. Disproportionate benefits hypothesis: perennial vegetation is expected to produce benefits disproportional to its extent within landscapes; ecosystem benefits of non targeted perennial cover (dashed line), ecosystem benefits of targeted perennial cover (solid line), and socio-economic benefits (dotted line). Examples of ecological benefits include clean water, flood control, pollination, pest suppression and outdoor recreational opportunities. Examples of social benefits include inspiration, connectedness and civic engagement.

landscapes are not utilized to produce food, fiber or fuel, but instead are maintained under perennial vegetation to produce other, less quantifiable or marketable products, are only beginning to emerge[28,29]. In particular, more information is needed about how different types, amounts and locations of perennial cover influence the cost–benefit tradeoffs of different ES[30–33], as well as the policy structures required to facilitate changes in land management practices and market mechanisms[31,34]. Moreover, because areas with perennial vegetation tend to support plant communities having greater species diversity relative to areas managed purely for agricultural crops, teasing apart the relative contributions of perenniality versus biodiversity to the provisioning of different ecosystems services is another challenge in perennialization research requiring greater attention.

In this paper, we argue that redesigning agroecosystems based on perennialization principles can dramatically improve the capacity of agricultural landscapes to provide valuable ES to society, while simultaneously producing sufficient amounts of food, fiber, fuel and bioenergy (Fig. 1). In this paper, we discuss how targeted integration of appropriate mixtures of perennial plants into agricultural landscapes offers a common unifying strategy for augmenting diverse ES, balancing food production with conservation, and enhancing agroecosystem resilience and stability. We focus our discussion on the humid temperate Corn Belt of the Midwestern US, a major global food-producing region accounting for approximately 40% of the world's total production of corn (*Zea mays*)[35]. The Corn Belt provides an excellent model

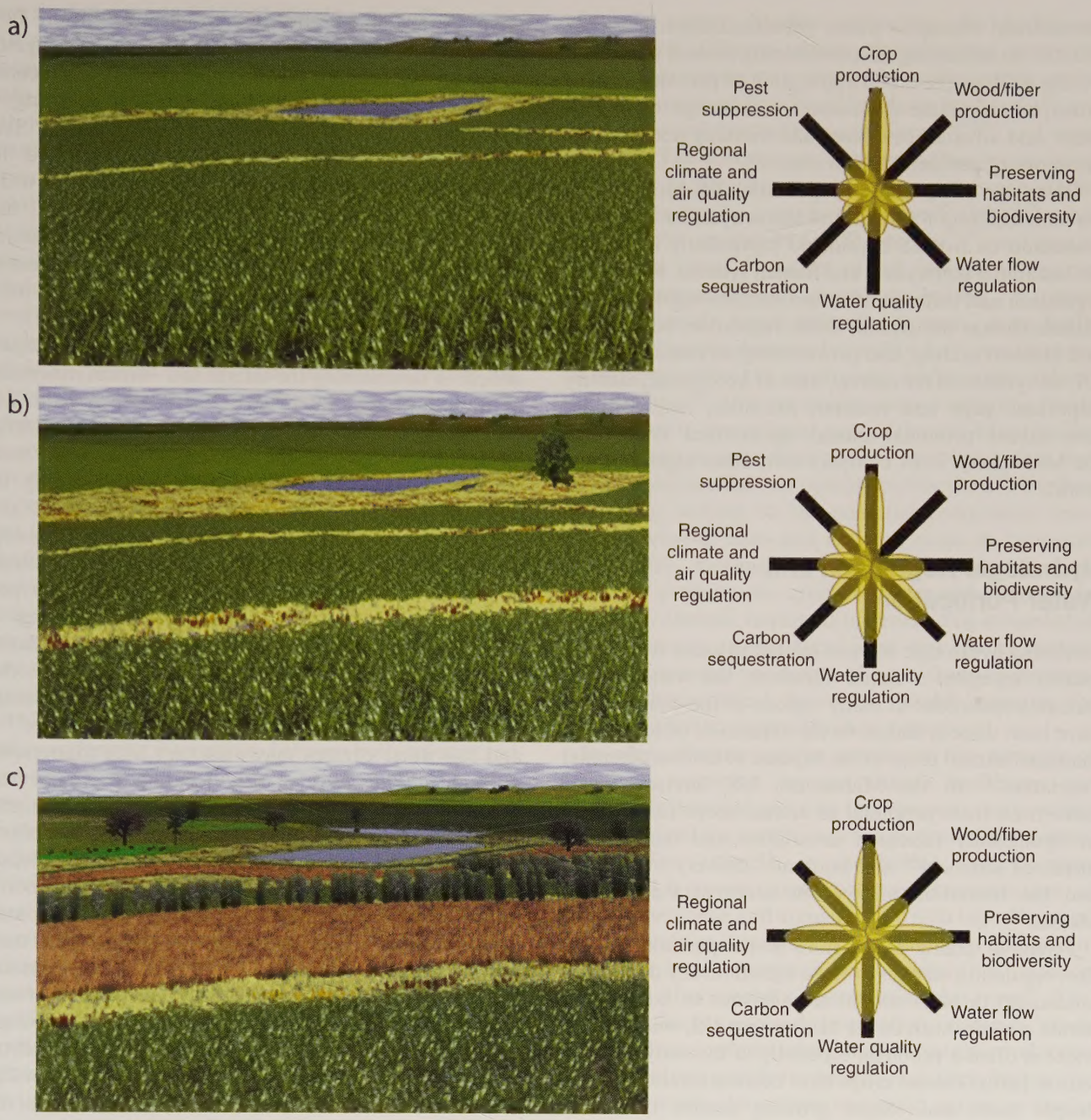

Figure 2. A virtual agricultural landscape with perennial vegetation that is strategically integrated in varying proportions (left) to enhance the delivery of ES, as illustrated in the 'flower' diagrams (right); the proportion of perennial vegetation in each landscape is as follows: (a) 4%, (b) 16% and (c) 64%.

system for our analysis because it has experienced one of the most pronounced landscape scale conversions worldwide, with ~70% of the pre-European native grassland vegetation replaced by monocultural annual crops of corn and soybean (*Glycine max*)[36]. Extensive drainage of natural wetlands together with intensification and mechanization of agricultural practices have accompanied the conversion process[37]. These land-use changes have severely compromised the delivery of fundamental ES to society, such as clean water[38,39], odor- and toxic-free air[40], flood control[41] and wildlife habitat[42]. Despite growing interest over the past several decades in perennial-based conservation practices in the region[6], a broader valuation of the multiple ES achievable through strategic targeting of perennial vegetation is needed (Fig. 2). We complement our analysis with examples from other regions (e.g., China, Africa and Central America) that have experienced similar trends of agricultural intensification and simplification, and where significant opportunities also exist for better balancing food production and ES through perennialization. Although a detailed global comparative analysis is beyond the scope of this paper, by highlighting

documented examples where perennialization has contributed on enhancing ES provisioning around the world, we aim to show the broad application of perennialization principles, stimulate cross-country exchange of experiences, and advance new ideas and thinking about future directions of perennialization research.

Given the wide range of potential ES provided by perennialization of agricultural landscapes, we focus our discussion on five ES considered particularly important for sustaining biophysical and human systems: hydrologic regulation and water purification, climate regulation and climate change mitigation, biotic regulation, soil quality and nutrient cycling, and provisioning services. For each ES, we synthesize the current state of knowledge, identify important gaps and research priorities, and consider how mixed perennial–annual agricultural systems in the Midwestern USA compare with other regions in the world.

Hydrologic Regulation and Water Purification

Declining hydrologic services related to water supply and quality represent a major threat to the well-being of human populations in many regions of the world[43], and have been directly linked to the expansion of intensively managed annual crops at the expense of diverse perennial vegetation[44]. In the Midwestern US, landscape-scale conversion from perennial to annual crops has resulted in significantly increased streamflow and base flow[45], increased sediment[46] and nutrient[47] delivery to streams, and the formation of hypoxic zones in the Gulf of Mexico[48].

Perennial plants can restore water purification and flow regulation services to these agriculturally dominated landscapes through several mechanisms. In humid temperate climates such as the Midwestern US, where excess water is often a problem, especially in the early growing season before annual crops have become established, the deeper roots and longer growing season typical of perennial vegetation results in greater total water uptake and evapotranspiration compared with annual crops[49,50]. Additionally, perennial vegetation can improve soil structure and hydraulic properties by increasing the number and size of macropores[51–53], building organic matter[53,54] and improving soil porosity[55,56]. Combined, these changes in plant water fluxes and soil properties contribute to greater soil water storage capacity[57], higher infiltration rates[58] and reduced runoff[59]. Perennial grasses[60,61], trees[62] and tree–grass mixtures[63] have also been shown to more effectively trap and retain sediment compared with annual crops.

Critical to developing effective perennialization strategies is a sound understanding of how much of the landscape needs to be converted to perennial cover, where such conversions are best located and which species mixtures are most effective. Studies based on both modeling[64,65] and empirical measurements[66,67] suggest a nonlinear relationship between the amount of perennial cover and different hydrologic services, resulting in diminishing returns beyond a certain amount. Such nonlinear relationships have been demonstrated for sediment trapping efficiency[61,63,68,69], retention of nitrogen (N), phosphorus (P)[68,70,71] and pesticides[72], and runoff reduction[55,56]. Combined, these findings underscore the notion that relatively small amounts of perennial cover may produce significant ES benefits, while minimizing negative impacts on crop production (Fig. 1).

The location of perennial vegetation in the landscape is critical in determining the lateral and vertical movement of water through watersheds. For example, Sahu and Gu[65] used a modeling approach to show that strips occupying 10–20% of the catchment area were more efficient in reducing NO_3–N when placed along the contour than along the riparian zone. Jiang et al.[73] found that perennial plants located on the backslope position showed greater improvement in hydraulic properties compared with summit and footslope positions, suggesting that targeting perennial plantings to slope positions that are most vulnerable to degradation may provide the greatest benefit–cost returns. Another important consideration is that hydrologic flows generally are not distributed uniformly along buffer strip edges[64,74], and soil water content may also vary with topographic position[75]. Thus, strategically locating perennial vegetation to maximize flow interception can optimize hydrologic regulation and water purification benefits[76]. Nonetheless, placement of buffer strips on the landscape under current practices is often dictated by economic factors[77], and more work is needed to incorporate approaches for identifying landscape positions for maximizing ES gains into policy and management decisions.

Few studies have assessed the interactive effects of both amount and location of perennial cover on the hydrologic functioning at the watershed scale. One study in central Iowa assessed the effects of varying amounts (10% or 20% of total watershed area) and locations (20% all at the bottom or 20% distributed in contour strips) of native perennial prairie vegetation on sediment and nutrient loss from experimental watersheds[78]. During an extreme rainfall year (2010), watersheds having 100% annual crops had up to 35-fold greater sediment loss (6412 kg ha^{-1}) compared with watersheds having perennial strips (180–314 kg ha^{-1})[61]. In a relatively dry year (2009), the differences among treatments were also substantial: 4114 kg ha^{-1} sediment lost from watersheds having 100% crops compared with 129–173 kg ha^{-1} from watersheds with perennial strips. Similar results were observed for N: during a wet year (2008) 100% cropped watersheds had 8-fold greater N export (83 kg ha^{-1}) relative to watersheds with perennial strips (8.1–12.3 kg ha^{-1}); the difference was 6-fold during a dry year (2009). Patterns observed for P losses were even more pronounced, with 100% cropped

watersheds having 11-fold and 16-fold greater P export in 2008 and 2009, respectively, compared with watersheds containing perennial strips. Annual total runoff was 1.6 times greater for watersheds with 100% crops compared with watersheds with the perennial strips[55,56]. Across all measured variables and years, watersheds with 10% perennial cover at the bottom unexpectedly performed slightly better than watersheds with 20% perennial cover distributed as contour strips, and the reason for this is believed to be due to a larger area in perennial cover at the footslope position for the watersheds with 10% perennial cover at the bottom. The 10% perennial cover at the bottom treatment had the greatest perennial cover at the footslope position rather than intermixed within the watershed so likely provided the greatest protection in reducing sediment and nutrient loss. However, over time the contour strips distributed within the watershed may provide a naturally terracing effect, which could improve the performance of this treatment. Overall, the findings from this study highlight the potential short-term (2–4 yr) benefits provided by strategically integrating small amounts (as little as 10% of the entire watershed) of perennial strips within annual cropping systems. More long-term monitoring is needed to understand the long-term functioning of these strips once they become well established.

Although we are unaware of other watershed scale field studies addressing interactions between both amount and location of perennial cover, several other approaches have been used to identify landscape locations for targeting perennial cover to maximize benefits. Geza et al.[78] used the Soil and Water Assessment Tool (SWAT) to evaluate environmental and economic trade-offs between placing grass filter strips along field drains or targeting their placement to environmentally sensitive areas. While the authors found that placement of the filter strips along field drains was more cost effective, they concluded that the targeted approach would be more environmentally beneficial due to the greater potential for enhancing soil conservation. Terrain analysis has been used to identify sites with large wetness indices[74], and soil survey and topographic and streamflow data have been combined to develop a system for prioritizing locations for maximizing sediment trapping and surface runoff and/or shallow groundwater flow interception[76]. Geographic information systems and multiple criteria ranking procedures have been used to identify the intersection of hydrologically sensitive and pollutant source areas to develop decision-making processes for effective buffer placement[79]. While these studies have generated similar conclusions—that targeting perennial cover to key areas in agricultural landscapes maximizes environmental benefits—supporting empirical data are lacking for a range of climatic and edaphic conditions.

The selection of particular species or functional groups (e.g., trees versus grasses) can also affect the hydrologic functioning of perennial vegetation, but information is relatively scarce. Studies comparing the hydrologic functions of different species of herbaceous perennials suggest that species may vary substantially in their ability to reduce overland flow[80] and herbicide leaching[81,82], and to increase sediment trapping efficiency[60,83,84] and water uptake[85]. The effectiveness of grass buffers versus mixed grass–tree buffers appears to vary, with some studies suggesting a similar capacity to remove N and P[9,86], while others report greater N and P removal[51,63] and greater infiltration rates[57,87] under mixed tree–grass riparian buffers compared with grass-only buffers. A paired watershed study found that after 9 years, grass buffer strips significantly decreased runoff by 8.4%, yet there was no significant effect of agroforestry buffer strips, relative to the control[88]. One reason for these contrasting results may be due to the different ages of the tree-based buffers as trees require more time to fully establish before they exhibit positive effects on hydrologic functions[89]. Further, research is lacking on the potential competitive interactions between trees and adjacent crops in temperate agroforestry systems, as water, nutrient and light resources available for crop growth may become more limiting[90]. Overall, improved understanding is needed of how differences in functional type and species composition of perennial vegetation affect hydrologic performance to better select the most suitable mixtures for achieving specific perennialization objectives.

In other climatic regions worldwide, the presence of perennial vegetation in agricultural landscapes can enhance hydrologic services, but impacts vary widely depending on site-specific agroecosystem–climate interactions. For example, in the humid tropics, many traditional agroecosystems comprise combinations of different perennial and annual plants with high structural and compositional complexity, and are often designed to both meet local subsistence needs while simultaneously producing a few specialty high-value market crops[91]. Two classical market-oriented production systems, shade coffee and cacao plantations, which target the production of perennial crops while maintaining relatively high native species diversity, have been shown to maintain similar hydrologic services compared with the native forests[92–94]. Hanson et al.[93] showed that following conversion of primary forests to grassland, soils had lower saturated hydraulic conductivity and more frequent overland flow compared with soils under traditional shade-grown coffee plantations, while the latter maintained high infiltration capacities and readily conducted water vertically, similar to conditions under primary forest. However, as a result of increasing market pressures and land-use intensification, many shade-grown agroforestry systems are being converted to less diverse and more structurally homogeneous sun-grown plantations[95,96] or, in some cases, to annual or short duration crops such as sugarcane[97,98] or oil palm[99]. These transitions from diverse perennial to simplified monocultural systems are often accompanied by negative consequences for hydrologic services[100]. Notably, this

example underscores the interlinked nature of biodiversity and perenniality: shade-grown coffee systems are typically managed for multiple products in addition to coffee, many for local consumption (e.g., fruits, herbs and medicinals), whereas a transition to sun-coffee generally involves more intensive management of a single product —coffee. Although difficult to disentangle, especially given the lack of controlled studies, it is likely that many of the ES that are enhanced by perennial systems are inextricably linked with the concomitant increase in biodiversity.

In contrast to humid climatic regions, in arid environments the extraction of too much water by perennials can be problematic for water supply, as water use by forests and shrublands is almost always greater than by croplands or grasslands[101] and planting trees typically reduces annual water yield[102]. In China, where large-scale revegetation initiatives in arid regions have resulted in the planting of millions of hectares of trees[103], a recent study found that the total water loss due to transpiration from a poplar plantation was 100% greater than that of adjacent shrubland[104]. Controversy over tree planting and water supply is especially acute concerning exotic species, with much of the debate focusing on fast-growing eucalyptus and pine species[105]. Crucial to determining the overall cost–benefit relationship of planting trees in drylands will be quantifying the net trade-offs between increased transpiration, on the one hand, and improved infiltration and water storage capacity and reduced runoff on the other[106]. Notably, trees in semi-arid regions may provide many ES that outweigh their increased water use, including fuelwood, timber poles, nutritional products and windbreaks[107], improving soil properties such as porosity[108], infiltration[109,110], water storage capacity[111], and nutrient cycling and soil fertility[112]. Trees may also increase water content in drylands by ameliorating microclimate and reducing soil evaporation[113,114], or by hydraulic lift or redistribution[115–117].

In semi-arid areas of Africa, the positive effects of trees in cropping systems are exemplified by farmers' use of *Faidherbia (Acacia) albida*, a leguminous tree with a reverse phenological pattern relative to most other trees (e.g., leaves drop in the wet season and flush in the dry season), which may reduce competition for resources with crops during the growing season. Crop yields in grain fields with interplanted *F. albida* trees have increased by over 200%, even without additional fertilizer inputs, while these mixed tree–food crop systems also provide multiple benefits such as fuelwood, fodder and enhanced food security during severe drought[118,119]. Similarly, in dry temperate climate regions in China, widespread incorporation of perennial plants into annual row crops is occurring[120,121], even though most of these lands do not have irrigation. These perennial plantings are being used to reduce sediment and pollutant export[122], stabilize dunes[120], conserve soil water and nutrients[123], enhance N-fixation[124] and supplement local economic incomes[104,125]. Another positive effect of planting deep-rooted perennials in some drylands, such as southern Australia and the African Sahel, is to alleviate problems of salinization of soils and groundwater by lowering water tables[43,126]. Studies have also demonstrated the influence of different types[127,128] and species[129,130] of perennial vegetation on enhancing hydrologic functions and reducing sediment and nutrient losses in these regions; however, relatively little work has specifically examined the importance of landscape position.

The impacts of incorporating perennial vegetation within cropping systems on hydrologic services are clearly being documented across different regions and agroecosystems, and these studies are highlighting the importance of considering both the local climate–vegetation interactions and management objectives when selecting suitable perennialzation approaches. Opportunities for significant hydrologic benefits through perennialization may be particularly strong in humid regions where enhanced hydrologic regulation is a priority, while significant ES gains are also being achieved in dryland regions through strategic placement of small amounts of perennial vegetation. More work is required to better understand how varying the spatial location, type and amount of perennial vegetation can differentially influence hydrologic outcomes, especially at the watershed scale, in order to maximize benefits under diverse climatic conditions.

Climate Regulation and Climate Change Mitigation and Adaptation

Although agroecosystems can provide important climate regulation services through carbon (C) sequestration and storage, they can also increase greenhouse gas emissions as a consequence of biomass burning or accelerated decomposition during forest conversion processes, as well as from chemical and energy inputs[131,132]. Whether an agroecosystem is a net carbon sink or source is directly influenced by management practices and their interaction with local biophysical and climatic conditions[133]. As diverse perennial plant communities typically store more carbon than annual or short-rotation cropping systems[10,134], perennialization provides an opportunity for mitigating climate change while sustaining agricultural productivity, especially when targeting those species combinations and landscape positions that maximize potential carbon sequestration benefits.

In the Midwestern US, the native tallgrass prairie ecosystem historically stored large amounts of carbon belowground relative to the annual cropping systems they replaced. Conversion of prairie to agriculture resulted in an estimated loss of 24–89% of the original soil organic C and total N[135–138]. Estimated annual accumulation rates of soil organic C following reestablishment of perennial grasslands on former agricultural lands vary

greatly, from 19.7 to 78 g C m^{-2} yr^{-1} in the upper 10 cm soil horizon[136,139–142], with average reported rates around 30 g C m^{-2} yr^{-2} [143,144]. However, rebuilding soil organic pools to pre-agriculture levels will require time. For the Great Plains region, McLauchlan[142] estimated that reestablishment of perennial grasslands on former agricultural lands could rebuild soil organic C pools to levels equivalent to unplowed native prairie within 55–75 years, while Matamala et al.[145] estimated that within a century restored tallgrass prairie vegetation in Illinois would reach 50% of its soil C storage potential. Differences in C accrual rates across sites and soil depths due to variation in root distribution, rhizosphere activity[146,147] and vertical retranslocation of soil C[47,146] may account for some of this variability.

Notably, C storage benefits are quickly lost when perennial vegetation reverts to annual crops, leading to rapid releases of CO_2 and other greenhouse gases to the atmosphere[140,148]. Gelfand et al.[149] examined the greenhouse gas consequences of converting land under the Conservation Reserve Program (CRP) to continuous corn, corn–soybean or perennial grass for biofuel production. They found that projected C debt repayment periods under no-till management ranged from 29 to 40 years for corn–soybean and continuous corn, respectively, whereas the use of existing CRP grasslands for cellulosic feedstock production would avoid C debt entirely and provide modest climate change mitigation immediately.

Landscape position can also influence the rate of C sequestration and storage potential of perennial vegetation. Some studies suggest that C sequestration potential may be maximized by placing perennial cover in topographical positions with higher moisture availability, such as footslopes and riparian areas[135,150]. On the other hand, because cultivation of sensitive areas such as shoulder and backslope positions may accelerate erosion of soil organic matter[151,152], targeting topographical positions that are vulnerable to erosion can promote C retention in the soil. More work is needed to refine understanding of the site-specific features that influence the relationship between topographic position and C sequestration.

Carbon sequestration potential in soils and plant biomass may also vary depending on both species identity[153] and functional composition[154] of the vegetation. In general, trees and shrubs sequester and store greater amounts of C compared with herbaceous plants due to their larger total above- and below-ground biomass[155]. In the Midwestern US, riparian buffer systems consisting of mixtures of native herbaceous and woody species sequestered significantly greater amounts of C relative to crop fields or cool-season grass buffers[54]. Nevertheless, grassland vegetation can be highly effective at accumulating C by depositing large amounts of organic matter deeper in the soil horizon where it is protected from decomposition[145,156]. Conversely, woody plants typically deposit a large fraction of total organic matter inputs on the ground surface, where decomposition occurs more rapidly[143]. Knowledge of how different species and functional groups affect rates of C sequestration, patterns of partitioning of C between above- and belowground biomass, and soil organic C accrual and depletion rates is important to take into account when using perennial vegetation as part of climate change mitigation strategies[157].

Not only do perennials store additional C relative to annual or simplified cropping systems, perennial plant communities may also enhance agroecosystem resilience and stability to environmental fluctuations, especially when they include high levels of biodiversity[22–24,158]. In the Midwestern USA, conservation agriculture practices are increasingly promoting the use of diverse mixtures of native tallgrass prairie species rather than plantings of a single native or introduced species typically used in the past (e.g., *Bromus inermis,* brome; *Bouteloua cuttipendula,* side oats; and *Panicum virgatum,* switchgrass).

Research suggests that grass and forb species typical to the native tallgrass prairie possess a variety of ecophysiological traits and adaptive strategies that enhance resilience and resistance to climatic extremes, such as high water use efficiency[159–161], the capacity to senesce and resprout[162,163], deep roots[164,165] and high ecological plasticity[166,167]. In addition, greater vertical and horizontal heterogeneity in more diverse plant communities allows for niche partitioning and complementary use of resources[168], which on the landscape scale can help buffer ecosystems against extreme climate fluctuations[169]. In contrast, annual crops in temperate humid climates are particularly vulnerable to extreme weather conditions, due to a combination of shallow rooting, a relatively short (3–4 months) growth period, high water demand, and high sensitivity to drought and heat stress[170–174]. Perennial plant communities with high species diversity may also have a greater probability of containing species with traits adapted to environmental changes, thus conferring greater 'insurance' relative to plant communities with low species diversity or monocultures[175,176]. Some experimental support for enhanced resilience in diverse perennial plant communities in the context of climate change is emerging[177–180], especially in terms of greater temporal stability[24]. Nonetheless, the relationship between biodiversity and the sustainability of ES is complex[27,181], and more work is needed to better design integrated annual–perennial landscapes capable of adapting to future climate change while sustaining diverse ES.

In the humid tropics, conversion of forests and traditional agroforestry systems to more intensive agricultural systems has contributed substantially to global greenhouse gas emissions and changes in C stocks[182,183]. In Central America and Mexico, agroforestry systems that maintain a significant tree component, such as shade coffee and cacao plantations, home gardens and tree farms, are particularly effective at sequestering and

storing C, while providing diverse agricultural products[184,185]. Kirby and Potvin[186] found that while native forests in Panama managed with selective logging stored more than twice as much C than forests managed under traditional agroforestry practices, agroforests stored three times more C than pasture. Expanding agroforests into pasture could provide additional biodiversity and livelihood benefits that the most common reforestation system in the region—monoculture teak plantations—does not provide. A meta-analysis examining the potential for soil organic C accumulation through afforestation found that planting trees on croplands resulted in more pronounced increases in soil organic C stocks relative to pastures or grasslands, and that broadleaved tree species had a greater capacity to accumulate soil organic C than coniferous species[187].

In dry climatic regions where plant growth is relatively slow and total plant biomass is low, the potential for sequestering and storing C per unit land area is generally less than in moist climatic regions. However, the total area of degraded drylands that could potentially be restored to perennial vegetation cover is so large that it constitutes a significant potential C sink[188]. Studies in dryland regions of Africa have shown that the amount of soil organic matter below tree canopies is significantly greater compared with open areas due to high inputs of leaf litter and higher root mass[189–191]. In the case of evergreen agricultural systems in semi-arid Africa (discussed previously), incorporating *Faidherbia albida* trees has been shown to accumulate between 2–4 $Mg\,ha^{-1}\,yr^{-1}$ of above- and below-ground C, which represents a 10-fold increase over conventional conservation farming systems[192–194]. Targeting of woody perennials in dryland regions for enhanced C storage should focus on the preservation or introduction of widely dispersed trees within agroecosystems in order to maximize total ES benefits, while maintaining a favorable balance between carbon–water trade-offs.

In semi-arid regions of Africa, the traditional agroforestry parklands are also used by local farmers to adapt and reduce vulnerability to climatic fluctuations and other extreme weather conditions. These parklands typically comprise several species and genera that constitute important sources of medicine, fruits, oils, leaves, nuts and spices that are main components of the local diet[115,195–197], while also providing fuelwood, feed and an additional income source[91]. Similarly, shade coffee agroforestry systems in the humid tropics have been shown to provide better protection for crop plants from extremes in microclimate and soil moisture relative to low-shade (10–30%) systems, thus representing an important adaptive strategy for farmers to future climatic extremes[198]. As woody trees and shrubs are often better able to survive extreme weather events such as droughts or floods, they are particularly important for meeting the nutritional and health needs of local people during times of food scarcity.

Although the potential for C sequestration in agricultural soils worldwide has been estimated to be relatively modest, representing approximately 3–6% of fossil fuel C emissions, practices that enhance C storage within agricultural landscapes are considered an important component of climate change mitigation strategies[199]. Globally, a meta-analysis by Ogle et al.[200] found that soil organic C was most sensitive to management impacts in tropical moist regions, followed by tropical dry, temperate moist and, lastly, temperate dry regions. Further, the tropics lose nearly two times as much C and produce less than one-half the annual crop yield compared with temperate regions[201]. This situation underscores the importance of avoiding clearing more tropical forests for agriculture while balancing agricultural intensification with targeted opportunities for C sequestration through perennialization of existing agricultural lands[182]. Another promising approach to promoting greater C sequestration on agricultural lands in both temperate and tropical regions is the use of perennial plants as biofeedstock for cellulosic ethanol production (potentially reducing the use of fossil fuels) combined with application of the charcoal by-product—the biochar—to agricultural soils to increase C storage over long time periods, given that biochar is highly recalcitrant to degradation (see the 'Provisioning Services' section for a more detailed discussion)[202,203].

Biotic Regulation

Perennialization can increase landscape complexity and resource heterogeneity, thereby promoting habitats for diverse communities of beneficial organisms that help control pests and pathogens, and provide pollination services in adjacent crop fields[204]. Perennials also contribute to food web services by providing habitat for organisms that are a food source for auxiliary biota in the productive or semi-natural sub-systems, and for biota that feed on crop pests[205].

As perennial vegetation is generally subject to lower levels of disturbance and is more stable over time than are ephemeral annual crop systems (with some exceptions, such as severe over-grazing and hay and grass silage production systems subjected to frequent harvests), various forms of perennial cover can provide critical elements of 'conservation biological control' strategies that seek to retain and facilitate populations of predators and parasitoids that attack arthropod pests in adjacent cropland[206–208]. Both within-field and around-field perennial vegetation can maintain and increase the impacts of natural enemies of crop pests through the provision of alternative prey species, pollen and nectar used as protein and energy sources, and habitat for over-wintering and reproduction[11,209–212]. Within-field diversification with perennial plants can be set up directly by individual farmers, whereas around-field diversification with perennials can reflect the

cumulative impacts of multiple landowners and land managers on landscape structure.

A number of studies indicate that increasing the proportion of landscapes occupied by woodlots, hedgerows, old-field fallows and pastures can enhance biological control of crop pests in fields embedded within those forms of perennial vegetation[213,214]. Tscharntke et al.[215] reported that parasitism of rape pollen beetles (*Meligethes aeneus* F.) was greater in German landscapes in which non-crop vegetation occupied >20% of total land area compared with landscapes in which non-crop vegetation occupied <20% of the land area. In the less diverse landscapes, parasitism of rape pollen beetles was greater at the edges of fields than in the centers; in contrast, in the more vegetatively diverse landscapes, parasitism rates did not differ between field edges and centers. Scale issues were addressed in a study conducted by Gardiner et al.[216] at sites within four states in the north central US. Densities of predatory coccinellid beetles and rates of biological control of soybean aphid (*Aphid glycines*) increased as the proportion of landscapes occupied by forest and grassland rose, and the proportion occupied by corn and soybean dropped, with diversity and composition evaluated at a scale of 1.5 km around focal fields explaining the greatest proportion of variation in coccinellid densities and biological control rates. Thus, for certain host-specific crop pests and their natural enemies, there is likely to be a need for coordinated management activities in establishing and maintaining perennial vegetation at the landscape scale.

Similarly, perennial vegetation can provide a higher abundance and greater diversity of refuges for pollinator populations that are essential for many fruit and vegetable crops. In agriculture, especially among pollen-limited crops, promoting pollination services is an important means of increasing productivity. In a review of pollination services for the leading food crops in 200 countries, Klein et al.[217] found that of a total of 107 crops traded on the world market that are directly consumed by humans (but excluding crops that are solely passively self-pollinated, wind-pollinated or parthenocarpic), 40% of these crops are highly to moderately dependent on animal pollinators. Significant declines in different pollinator species have been documented in the Midwestern US, raising several ecological and economic concerns[218–220]. Grixti et al.[218] noted that half of the bumblebee species found historically in Illinois have been locally extirpated or have suffered declines, supporting observations of broader declines in North America. Major declines in the bumblebee fauna coincided with large-scale agricultural intensification. Bee richness was positively related to plant richness and abundance of potential nesting resources, and bee community composition was significantly related to plant richness, soil characteristics potentially related to nesting suitability, and canopy cover[219]. Conservation of agriculturally important pollinators may be promoted by applying wildlife-friendly approaches to agriculture, such as increasing agricultural land set-asides and hedgerows[220].

In humid temperate regions, perennial cover crops growing beneath 'main' crops have been shown to contribute to biological control, but they can also reduce crop yields through competition for water and nutrients, making their use problematic in many situations[221–224]. An alternative form of within-field diversification involves the use of narrow strips of perennial vegetation that provide habitat for predators and parasitoids of pests in closely adjacent cropped areas. This approach has been studied in wheat fields where perennial grasses function as 'beetle banks,' conserving coleopteran predators that forage on cereal aphids[225,226], and in vineyards where strips of flowering plants provide nectar and pollen sources and a corridor from riparian areas for predators attacking thrips and leafhoppers[227]. Strips of alfalfa (*Medicago sativa*) have been shown to conserve predatory beetles, bugs, lacewings and spiders, and increase their densities in adjacent strips of cotton, thereby exerting greater control of mirid and lepidopteran pests[228]. Strips of perennial grasses, legumes and other forbs left unsprayed with pesticides formed refuges for predatory ground beetles, permitting rapid recolonization of chemically disturbed corn[229].

Compared with arthropod pests and their natural enemies, the effects of perennial vegetation on crop diseases have received much less attention from the scientific community. In artificially constructed assemblages of perennial prairie species, increases in plant species diversity reduced the severity of diseases caused by wind- and rain-dispersed pathogens on four target plant species (*Septoria liatridis* on *Liatris aspera, Uromyces lespedezae-procumbentis* on *Lespedeza capitata, Ersiphe cichoracearum* on *Monarda fistulosa*, and *Colletotrichum* spp. on *Schizachyrium scoparium*)[230], suggesting that diverse mixtures of perennial species interplanted with crops might offer protection against certain pathogens. Such protection could occur as the result of non-crop vegetation acting as a barrier against propagule dispersal, hosting antagonistic and competitive microbes, altering microclimate conditions or inducing resistance within crops[231]. Perennial grain crops may also be bred for high levels of disease resistance. Hayes et al.[232] noted that wheatgrass species (*Thinopyrum* and *Agropyron* spp.) conveyed resistance to many diseases when crossed with wheat to produce perennial hybrids.

Cox et al.[233] noted that typical cultural practices for reducing soil- and residue-borne pathogens, such as annual crop rotations, delayed planting dates and tillage, are not feasible in perennial crop systems, and that as a consequence, pathogens that survive in soil, crop residues, live shoots and roots may become an increasing threat to perennial crops and adjacent areas of susceptible annual crops over time. To impede the build-up of pathogen populations, Cox et al.[233] suggested three approaches: planting mixtures of perennial crop cultivars

or species that vary in disease resistance to particular species and strains of pathogens; using grazing to remove plant residues; and burning plant residues, a natural phenomenon in perennial grass systems that can decrease the incidence and severity of a number of diseases. These methods remain to be field-tested in perennial crop and mixed perennial–annual crop associations, however.

The pest problem is especially important in the humid tropics, where the high rainfall and low seasonality favor two key groups of natural plant enemies—insects and fungi[234]. Consequently, the potential for losing crops to disease is far greater than in more temperate climates. Conserving both the associated fauna within tropical agroforests and surrounding forest fragments with high quality agricultural matrices is critical to maintaining pest regulation services[235]. For example, levels of ant biodiversity exhibit sharp declines with the intensification of coffee and cacao production systems compared with traditional agroforestry systems[236]. High diversity and abundance of ants provide important ES in coffee agroecosystems since ants are an important predator group[235,237]. Another predator studied in the coffee agroforest, birds, helps control coffee berry borers and thus increases coffee yield and farm income, a potentially important conservation incentive for producers[238,239]. Landscape heterogeneity may allow mobile predators to provide pest control broadly, despite localized variation in farming intensities. Similarly, forest remnants provide nearby coffee plantations with a diversity of bees and other pollinators that can increase both the amount and stability of pollination services by reducing dependence on a single introduced pollinator[240–242], and improve both quantity and quality of coffee yields by reducing the frequency of misshapen seeds[242].

Recent studies in the dry tropical zone have documented the importance of hedgerows (often planted for soil conservation purposes along sloping land) for enhancing biological pest control by serving as refugia for predators. Girma et al.[243] found that corn associated with hedgerows comprised of nine different species experienced significantly lower stalk borer (*Busseola fusca* and *Chilo* spp.) and aphid (*Rhophalosiphum maidis*) infestations than pure stands of corn. The study also found, however, that hedgerow effects on pest infestations of crops cannot be generalized but depend on the specific arthropods and their refugia preferences[243].

Trees have been shown to affect pest infestations in dry tropical agroecosystems by acting as barriers to movement of insects, masking the odors emitted by other components of the system, and sheltering herbivores and natural enemies[244]. In sub-Saharan Africa, where the corn stalk borer, *Busseola fusca* (Full) (Noctuidae), and the sorghum stem borer, *Chilo partellus* Swinh (Pyralidae), pose major threats to food production, Khan et al.[245,246] reported positive effects of trap crop plants (Napier grass, *Pennisetum purpureum,* and Sudan grass, *Sorghum sudanensis*) and intercrop plants (molasses grass, *Melinis minutiflora,* and *Desmodium* spp.) for controlling stem borer outbreaks through release of attractant and repellent semiochemicals.

Currently, it is difficult to view perennial vegetation as a panacea for crop pest and disease problems, though promising opportunities for improved management strategies clearly exist. The generally positive influence of perennial vegetation on biological control is not necessarily consistent from year to year[247]. Moreover, in some cases perennial vegetation can exacerbate pest problems by serving as an alternate host to crop pests, as is the case for soybean aphid, which resides on buckthorn (*Rhamnus* spp.) growing in hedgerows and woodlands adjacent to soybean fields in the Midwestern USA[248]. Much more needs to be learned concerning sources of spatial and temporal variability in the effects of perennial vegetation on natural enemies of crop pests and crop disease dynamics, and a much more detailed understanding needs to be developed concerning how individual perennial species affect natural enemies of arthropod pests, crop pathogens and crop yields.

Soil Quality and Nutrient Cycling

Soil quality is the capacity of a soil to sustain biological productivity, maintain environmental quality, and promote plant and animal health[249,250]. Consequently, soil quality is a required supporting service for agroecosystems and human societies. Over the past several decades, soil scientists have assembled sets of physical, chemical and biological indicators of soil quality[249]. Physical indicators include rates of water flow into and through soil; soil structural characteristics, such as porosity, bulk density and aggregate size distribution; and measures of stability, such as aggregate stability in water and erosion rate. Chemical indicators include quantities and qualities of soil organic C and N, nutrient availability to plants and soil reaction (pH). Biological indicators include the mass of organisms in soil and measures of their physiological activity, including rates of respiration and enzymatic reactions.

Regular additions of organic matter, especially root materials, play a critical role in the maintenance of soil quality[251,252]. In general, in humid, temperate environments, woody and herbaceous perennial plants add more root material and organic matter to soil than do annual crops[53,54] and consequently they are more effective at maintaining soil quality. As noted in the previous sections on hydrologic regulation and climate regulation, rainfall infiltration, hydraulic conductivity and soil C storage are greater for soil occupied by trees and herbaceous perennials than annual row crops.

Adding perennial crops to rotation sequences dominated by annual crops can have beneficial effects on soil quality and function. Residues of alfalfa, red clover and

other perennial forage legumes can release enough N to satisfy much or all of the nitrogen demand of subsequent cereal crops, such as corn nitrogen[253,254]. Russell et al.[255] compared cropping systems based on annual crops (continuous corn or a corn–soybean rotation) with systems that contained alfalfa as well as corn and soybean and found that systems containing alfalfa had greater available N, higher rates of potential net N mineralization, and more microbial biomass C. Soil total N and organic C concentrations were also higher in systems containing alfalfa. Thus, cropping systems that contain perennial legumes in sequence with annual crops can have lower requirements for fertilizer and higher rates of soil C storage[256,257].

More efficient N use by perennials can potentially reduce the environmental impacts associated with nutrient losses. Nitrogen losses to drainage water are greater for corn and soybean than for perennial grasses and herbaceous legumes such as alfalfa[258]. Moreover, trees can have even higher N and P removal efficiency than perennial grasses[54,67]. In Iowa, N immobilization rates in poplar stands and switchgrass sites averaged 37 and 16 $kg\,N\,ha^{-1}\,yr^{-1}$, respectively[54].

For humid tropical regions, which typically have soils of low fertility[259], it is especially important to develop land-use systems that promote efficient nutrient cycling[260]. Land-use systems based on tree crops (e.g., multistrata agroforestry systems) have clear advantages over annual cropping systems for the maintenance of soil fertility because they provide permanent soil cover and root systems[260]. For example, when shade coffee agroforestry systems are converted to more intensive sun-grown systems by removing the shade trees, N fertilizers are usually applied at high rates to maintain productivity. Research assessing the consequences of these changes for nitrate leaching and water quality has yielded contrasting results[261–263]. Babbar and Zak[261] reported lower N leaching rates from shaded than from unshaded coffee cultivation in Costa Rica (9 versus 24 $kg\,ha^{-1}\,yr^{-1}$, respectively), though plantations differed in the density and pruning regime of the coffee plants, making the data difficult to interpret. Harmand et al.[263] found that drainage was slightly reduced in a shaded compared with an unshaded coffee plantation, but N losses in surface runoff were low in both cases. In general, shade coffee systems appear to have greater potential to enhance other soil fertility properties such as nutrient and organic inputs from litterfall[262,264] and earthworm density[265] than their unshaded counterparts.

In arid agricultural regions of East Africa, retaining savanna trees as part of annual cropping systems can enhance soil fertility[266] and, in turn, understory crop production[267,268]. Perennialization can also help mitigate or even reverse processes of soil loss and desertification, common in many drylands, by reducing the movement of sand, retaining soil organic matter and promoting establishment of new vegetation. For example, in the Loess Plateau region of China, Qiao et al.[120] demonstrated that mixed tree plantations interspersed within cropland can, over time, help stabilize and facilitate the restoration of native vegetation. Yuan et al.[269] studied the effects of mixing wheat with three perennials (*Stipa bungeana, Lespedeza davurica* and *Artemesia capillaries*) in the same region, and found that the perennials significantly increased the total crop production, especially root growth.

Overall, the influence of perennials on soil fertility is synergistically coupled with their impact on hydrologic and C sequestration services, and thus, multiple ES can be obtained through perennialization processes in cropland. However, as with hydrological and C sequestration services, more work is needed to improve understanding of how different species mixtures, amounts and landscape positions influence soil quality properties, in both temperate and humid agroecosystems.

Provisioning Services

Food, fiber and fuel production to meet subsistence or market needs is the overwhelmingly dominant goal of agriculture. Crops in individual fields are dependent on services provided by nearby ecosystems, whether native or managed, and nearby ecosystems are often influenced by their agricultural neighbors[7]. As discussed above, perennialization can contribute toward maximizing ES benefits from agricultural landscapes. Below, we review opportunities for accomplishing this goal, with an emphasis on the additional provisioning services that perennial plants also provide.

Forage crops

Following the large-scale introduction in the 1940s and 1950s of relatively inexpensive synthetic fertilizers, farming systems in humid temperate regions have become increasingly specialized, with fewer crops grown within rotation sequences and fewer livestock enterprises integrated with crop enterprises[270,271]. As a consequence, in regions such as the US Corn Belt, annual grain crops such as corn and soybean have greatly displaced perennial forages, and cattle are often produced in large feedlots, from which manure application to a sufficiently large land base can be problematic. Nonetheless, recent increases in fertilizer and feed costs have led to renewed interest in integrated crop–livestock systems that include perennial species used for pasture and hay, and which exploit the recycling of C and nutrients via manure application to croplands[272]. Expanding crop sequences based only on annual species to include perennial forages, and returning manure to croplands, can have numerous benefits. As summarized by Russelle et al.[273], these include reduced nitrate leaching to groundwater, reduced rates of erosion by wind and water, increased soil C content and soil water

holding capacity, greater biological N fixation and improved nutrient supply, reduced incidence of pests, enhanced grain yield potential, lower fossil energy demands, reduced production costs and improved profitability. Despite these advantages, major disincentives to crop–livestock integration can exist within government farm policies. In the US, for example, disincentives have included subsidies for annual crops, but not perennial forages, and a lack of accounting for costs of the environmental impacts of farming systems. In contrast, Sulc and Tracy[271] noted, '... there is significant research investment in and adoption of integrated crop–livestock systems in countries where government price supports for agriculture are limited or nonexistent (e.g., Brazil, New Zealand).'

Grain crops

Although all of the world's current staple grains are annual species, concerns over soil erosion, agrichemical pollution, maintenance of soil organic C stocks and energy costs of tillage have propelled interest among some plant breeders in the development of perennial grain crops[149,274]. Cox et al.[274] reviewed parental germplasm and methodologies for breeding at least 20 species of perennial grains. Possible approaches to developing perennial grain crops include using related perennial species to add genes into annual crops such as wheat, and domesticating existing perennial species, such as intermediate wheatgrass (*Thinopyrum intermedium*), Maximilian sunflower (*Helianthus maximiliani*) and Illinois bundleflower (*Desmanthus illinoensis*), through selection for higher seed production and desirable agronomic and quality factors. Important biological and technical challenges exist for both approaches, but these might be surmountable in much less time than the millennia that were required to domesticate wheat, maize, rice and other grains[71].

Perennial grain crops may have a lower yield potential than annuals due to trade-offs between seed productivity and longevity: resources that might be allocated to seeds may instead have to be allocated to non harvested perennating structures to maintain survival from year to year[275]. Cox et al.[275] argued, however, that perennial grain crops do have the potential to produce high and acceptable seed yields because (1) compared with annual crops, perennials tend to have longer growing seasons, greater canopy cover duration, and deeper rooting depths, allowing them to intercept, retain and utilize more precipitation, nutrients and light; and (2) perennials generally produce more above-ground biomass than do annuals and a greater proportion of that biomass might be reallocated to grain production through breeding. DeHaan et al.[276] and Van Tassel et al.[277] noted that low yields from perennial grain crops to date reflect a lack of attention from plant breeders and they predicted that artificial selection in a properly managed agricultural environment could increase seed yield while maintaining perenniality. In one of the few studies reporting the seed yields of perennial grain crops subjected to artificial selection, Scheinost et al.[278] observed that promising lines of perennial wheat produced 1.7–5.8 $Mg\,ha^{-1}$, as compared with 9.0 $Mg\,ha^{-1}$ from an annual wheat cultivar commonly grown in the area. Murphy et al.[279] reported that amphiploid breeding lines derived from crosses between annual wheat and the perennial wheatgrass species *Thinopyrum elongatum* produced mean grain yields of 0.6–2.2 $Mg\,ha^{-1}$, depending on location, which were about 44% of the seed yield of annual wheat grown at the locations. It remains to be learned how much improvement in perennial grain yields can be realized through breeding. Adjustments in soil fertility may be necessary to increase the seed yields of perennial grain species. Loeppky et al.[280] reported that in northeastern Saskatchewan, seed yields of crested wheatgrass (*Agropyron cristatum*) and intermediate wheatgrass (*A. intermedium*) could be increased with the application of N and P fertilizers on soils with low levels of available nutrients. Additional research is needed to better assess the economics of perennial grain production systems, since reduced revenues due to lower yields might be offset by reduced input costs for seeds and land preparation.

Biofuel crops

Growing concerns over the instability of petrochemical prices, heavy dependence on foreign sources of petrochemicals and the environmental impacts of fossil fuel combustion (including greenhouse gas emissions) have led to rapid growth during the past decade in the use of plant materials to produce liquid transportation fuels. In the humid temperate zone, major emphasis has been placed on the use of corn grain to produce ethanol, and soybean and rapeseed to produce biodiesel. The resulting rise in prices of these crops has been viewed favorably by many crop farmers, but has also given rise to pointed critiques on a number of grounds. Partly, but not entirely, because of increased demand from the bioenergy sector for commodity crops, livestock feed costs and food prices for consumers jumped upward in 2006–2007 and may in the future impose financial and nutritional burdens on low-income people in both developed and developing countries[281]. Increased crop prices may also spur conversion of land currently in perennial vegetation to arable cropland, with attendant increases in N emissions to water supplies[279] and greenhouse gas emissions to the atmosphere[149,282,283].

Increasing attention to the development of thermochemical and biochemical technologies for converting lignocellulosic materials into liquid fuels and other industrial chemicals adds new twists to the biofuels story. Unlike the currently dominant biofuel technologies that rely on the use of seeds, lignocellulosic conversion processes utilize plant stems and leaves. Consequently,

research is being directed to the use of perennial grasses, such as switchgrass (*Panicum virgatum*) and miscanthus (*Miscanthus* spp. and interspecific hybrids such as *M.* × *giganteus*), and fast-growing tree species, such as poplar (*Populus* spp.) and willow (*Salix* spp.), as dedicated bioenergy feedstock crops[284–289]. Precedence for the use of dedicated perennial crops as biofuel feedstocks has already been set in Brazil, where sugarcane (*Saccharum officinarum*) is used for ethanol production[290].

Concerns have been raised over the potential for perennial bioenergy crops to become invasive pests[291], and protocols should be in place to avert this problem before introductions of non-native species or newly developed genotypes proceed. Tilman et al.[24] proposed the use of diverse mixtures of native prairie plants as bioenergy feedstocks on degraded, low-fertility land, which minimizes risks of introducing noxious species, but also limits the quantities of biomass that might be produced. Further, while removal of large amounts of annual crop biomass can reduce soil fertility and organic C stocks[292,293], removal of above-ground portions of perennial plants used as bioenergy feedstocks can still allow for the maintenance of soil fertility and organic carbon, since large quantities of nutrients are translocated below ground before shoot harvest, and the more extensive root systems of perennials can sequester sizeable amounts of carbon[283,294–296]. Residues of biofuel feedstocks can be spread after processing on soil as amendments to return nutrients and C[297,298].

An important option for the production of perennial biofuel feedstock crops is to use them as one element of multifunctional agricultural landscapes[299]. By placing well-adapted perennial biofuel crops on small, but vulnerable portions, of landscapes, soil, water and wildlife conservation benefits might be gained, while providing farmers an additional opportunity for producing a marketable crop[6,300]. Rotations including perennials and crops, given an appropriate level of management, could be a great opportunity to support the production of biomass and grain while maintaining soil quality over the long term on high-quality agricultural lands. This is especially important in regions with low fertility and where nutrients remain a major constraint, such as in rain-fed farming systems throughout the tropics. Perennials have also been proposed as the major bioenergy plants for the dry temperate zone of China, including short-rotation woody plants and native *Achnatherum* spp., *Agropyron*, and other species[301].

Medicinal products

Another valuable service of perennial plants integrated within agricultural landscapes in many regions worldwide is to provide medicinal products. In China, regardless of Western advances in medical sciences, people rely heavily on medicines derived from combinations of locally produced plants and animals; the majority of medicinal plants are perennials[302,303]. In Xingjiang Province alone, for example, 2014 plant species have been used in medical practices, among which 558 species are cultivated[125]. In the dry tropics of Africa the situation is similar, with a long and rich history of traditional use of perennial plants as medicines, and new phytochemical research has started to link specific plant properties with targeted effects on human health[304,305]. In the wet tropics, there is a long tradition of producing medicinal plants as integral components of home gardens[91].

The above discussion calls attention to the wide range of opportunities that exist for contributing a diverse array of food, fiber and fuel products to human societies through perennial plants. In some cases, these agroecosystems may be dominated by perennial plants, such as in the case of large-scale biofuel production or rotational cropping or grazing systems, but in many situations, they will likely involve the targeted placement of relatively small amounts of perennials in strategic locations as part of a matrix of annual crops. An important focus of future research will be to identify which landscape positions—as well as how much and what type of perennial cover—will provide the greatest benefit in terms of both agricultural products and other diverse ES under contrasting climatic conditions, and to meet different production goals by local communities.

Conclusions

As the global society faces the challenge of meeting increased demand for food, fiber and animal feed to sustain growing populations, while at the same time adapting to a changing climate, agricultural landscapes will likely undergo unprecedented transitions in the near future[306]. Central questions will involve determining the relative value and priority to be given to the many ES provided by agricultural landscapes in addition to food, fiber and feed, and how to best balance these multiple benefits, or in other words, how to harmonize agricultural production and conservation[307]. In this paper, we used the Corn Belt region of the Midwestern USA as a model system for highlighting examples where scientific research on perennialization of agricultural landscapes has documented progress toward achieving this goal. In particular, we showed how a targeted approach identifies landscape locations and the type and amount of perennial cover for maximizing benefit–cost trade-offs for multiple ES important to society, and thereby providing opportunities for designing multifunctional agroecosystems. We also emphasized that because perenniality and biodiversity are often inextricably and positively linked, and most studies on perennialization to date have not considered their independent effects on enhancing ES, more work in needed to disentangle the relative importance of these two variables. Finally, we highlighted differences in both the constraints and

opportunities for perennializing agricultural landscapes among different climate regions globally, in addition to critical gaps in knowledge where more information is needed. Notably, the evidence to date regarding the potential contributions of perennialization to balancing agricultural production and conservation are primarily based on controlled field studies such as those mentioned in this review; the effectiveness of perennialization approaches at the operational scale with farmer participation remains to be tested in the future.

Although an in-depth discussion of the political and socio-economic environment needed to promote perennialization is beyond the scope of the present paper, it is important to acknowledge that effective policy structures and mechanisms, market opportunities, institutional frameworks and infrastructural arrangements will be critical to establish incentives that favor adoption of perennial-based agricultural practices[308,309]. One of the major current constraints to perennialization is that the most economically profitable decision is frequently to grow only a few crop types, and not to invest in conservation of the varieties that are less favored by existing markets. The problem lies both in the public good nature of conservation, and the fact that currently there are no major markets for off-site ES that depend on on-farm agrobiodiversity[310]. Notwithstanding, there are a growing number of initiatives worldwide that seek to create markets for these services, ranging from those based strictly on government intervention to others that are entirely private ventures[311,312]. In the USA, the Conservation Reserve Program (CRP) provides monetary incentives to farmers to put cropland into various forms of perennial vegetation, with the original intent of reducing soil erosion. However, this mechanism is vulnerable to fluctuations in land and crop values, as seen by the rapid broad-scale conversion of CRP back to crops in recent years in response to the increasing biofuel economy[313]. In the developing world, examples of policies to counter market drivers favoring conversion of traditional, highly diverse perennial-based agroecosystems to more simplified systems include mechanisms such as certification[314,315], payment for ES[316–318] and reducing emissions from deforestation[319].

Moreover, it will also be important to quantify the economic implications of perennialization that include the less tangible values of the ES and not only the crops. There are several examples suggesting positive relationships between increasing agroecosystem biodiversity and income for different ES, including pollinator abundance[222,320], pest control[219], C sequestration[319] and water quality protection[100,321]. Gallai et al.[320] estimated that the total economic value of pollination worldwide at $153 billion, which represents 9.5% of the value of the world agricultural production used for human food in 2005. With rare exception, these services are neither prized by markets nor explicitly protected by the law, even though economic studies propose that properly constructed markets would support strong conservation measures[2]. For public policy decisions to take them into account, non market valuation techniques are urgently needed[7]. Economic and social benefits may also be conferred by perennial vegetation through enhanced resilience and stability of agroecosystems, thereby contributing to society's ability to adapt to and cope with climate change[322–324].

In order for perennialization practices—and the policies and programs that promote them—to be effective in the long term, scientifically sound data quantifying the effects of perennialization on different ES and identifying specific practices—in terms of what, where and how much perennial cover—that produce maximum benefit–cost trade-offs, will be critical. Our review of the literature suggests that there is substantial scientific evidence suggesting that increasing the presence of perennial vegetation in cropping systems generally leads to greater ES. However, current knowledge about the relationship between the spatial configuration, amount and type of perennial vegetation, and the specific ES impacts is relatively scarce. Further, long-term, replicated studies at the watershed scale, which are critical to addressing the impacts of perennialization on hydrologic services and their relation to other ES, are particularly lacking. Finally, there is generally more information available from temperate climate regions compared with tropical regions. Future work should focus on advancing scientific understanding to address these gaps in order to provide a baseline for designing approaches that enable targeting the placement of appropriate amounts and types of perennial vegetation in strategic locations on the landscape to minimize economic and production costs while enhancing ES.

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Organic agriculture in Iran: Farmers' barriers to and factors influencing adoption

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Abstract

Organic agriculture is being promoted in Iran to address environmental problems resulting from the use of chemical materials in agriculture. Despite many advantages of organic agriculture, the results of several case studies show that its adoption rate is still very low among farmers. The purpose of this paper is to review previous studies that investigated the main factors influencing and challenging the adoption of organic agriculture. The review included journal articles and conference papers from 2007 to 2012. The results show that Iranian farmers have strong motives for the adoption, yet face challenges in certifying, marketing, and accessing reliable technical information and credits. Given the review of factors that govern farmers' adoption of organic agriculture, key mechanisms for promoting farmers' adoption are discussed. Further research is needed to learn how to bring these mechanisms into play in Iran.

Key words: organic agriculture, renewable agriculture, sustainable agriculture, farmers' attitude, small-scale farming

Introduction

Organic agriculture (OA) is a production system that sustains the health of agro-ecosystems and people[1]. Organic operation can contribute to a sustainable food production system[2], improve employment opportunities, especially for women[3], improve household food security[4], enhance biodiversity[5] and contribute to agricultural development[6].

Many countries promote OA to avoid facing larger problems with unsafe food supplies, health problems, unsustainable agri-rural development and environmental degradation, among others[7]. In Iran, the advantages of organic farming are widely appreciated by different stakeholders, including policy makers, extension workers and researchers[8]. However, despite the rapid growth of OA in much of the developed world[6,9,10], the expansion of OA in developing countries, including Iran, has been much slower than in the developed world[7]. Only one-third of the world's organic agricultural lands—12.5 million hectares (ha)—are located in these countries[11]. In such countries, certified organic food production is generally limited[12]. Similarly in Iran, OA lands comprised 7256 ha in 2010. The key organic products in Iran consisted of pistachio (1382 ha), wheat (1156 ha), rose (900 ha), fig (780 ha), raisin (700 ha) and date (595 ha). In 2011, more than 95% of organic products in Iran were exported to European countries[13].

The first Iranian national plan to promote sustainable agriculture was initiated in 1995, entitled Optimal Utilization of Fertilizers and Pesticides. The plan was a ten-year program aimed mainly at decreasing poisonous residuals in agricultural products. The plan could not achieve its goals after 10 years, largely because of the low participation of farmers[14]. The process of OA promotion is still in its early stages in Iran. Integrated Pest Management/Farmers Field School (IPM/FFS) are recognized as extension approaches for promoting OA. High-level IPM (i.e., preventive practices to control pests) is considered a first step in promoting organic farming systems. The majority of farmers who are involved in the IPM/FFS projects in Iran are increasingly shifting to OA[15,16]. Consequently, the IPM/FFS sites have been established in pilot farms throughout the country in search for more participatory approaches for the dissemination of OA[17].

Despite the important impact of the IPM/FFS initiatives, the results of case studies[17–20] show that farmers have

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Table 1. Farmers' barriers to adopting OA in Iran.

References	Key barriers				
	Certification	Market	Knowledge and information	Workload	Costs
Omani and Chizari[38]					*
Moradi et al.[29]		*			
Asghar-Nejad and Tahmaseb-pour[30]		*			
Rezvanfar et al.[19]	*				
Etehadi et al.[15]			*		
Karimi[20]	*	*		*	
Hashemi-Nejad and Rezvenfar[31]		*	*		*
Sharifi et al.[25]	*	*	*		*
Etehadi et al.[17]			*		
Keshavarz et al.[28]		*			
Javanmard and Mahmoudi[27]		*	*	*	*
Mahdavi-Damghani[23]	*				
Khaledi and Weseen[24]	*	*	*		
Osku et al.[37]			*		

not adopted sustainable and organic farming practices entirely. What makes it difficult for policy makers and practitioners to promote OA in Iran is that Iranian farmers' motives and challenges toward adopting OA are still unclear. Because the issue has only recently come to the researchers' attention, there are few qualified research studies[19]. In addition, these studies have mostly considered experts' attitudes toward the dissemination of OA, not those of farmers. Finally, the case studies on farmers' attitudes, reported from different areas, lack methodological consistency.

The purpose of this review was to identify and summarize previous studies on Iranian farmers' attitudes toward OA, with the aim of drawing a comprehensive picture of the issue. Furthermore, this paper aims to identify mechanisms that may stimulate the adoption of organic practices among farmers.

Methodology

Case studies were reviewed to identify factors that influence farmers' decisions to adopt OA practices (e.g., biological pest and weed control, composting, cover cropping, green manuring and green leaf manuring, intercropping, living fences, microbial bio-fertilizers, multi-cropping and multipurpose trees). The main keywords used to obtain the documents were 'organic agriculture' and 'organic farming' followed by a combination of 'farmers' attitude', 'farmers' adoption', 'farmers' challenges' and 'IPM/organic'. IPM was included, because, as mentioned previously, IPM/FFS have been the main mechanisms to foster OA through participatory tools in Iran. Among the articles, quantitative studies were selected, which used questionnaires to determine farmers' barriers to and motives for adopting IPM and organic practices. Some inclusion and exclusion criteria[21] were used to conduct a more focused search. Inclusion criteria included studies that contained information about the adoption of OA practices, and assessed farmers' points of view. Abstracts or unpublished studies were excluded from the review. The date of released documents, which were either in English or Persian, was limited to 5 years (2007–2012). The data were obtained from four possible databases: scholarly journals in Persian ($n=13$), scholarly journals in English ($n=6$), Iranian conferences in Persian ($n=12$), and international conferences in English ($n=3$). The key findings of each study considered were those statistically significant factors affecting farmers' attitudes. Most articles used case study or survey methodology.

Results

Among the 34 reviewed studies, some discussed the farmers' barriers of adoption, some addressed their motives for adoption and others investigated both. The following presents our findings about the farmers' barriers to and their motives for the adoption of OA.

Farmers' barriers

Table 1 describes the most important barriers of Iranian farmers to the adoption of organic farming.

Certification. Some studies on the barriers of adopting OA in Iran found that certification is one of the main challenges for farmers[19,22–25]. This has been mentioned as a critical challenge for farmers in many other developing countries as well[26]. According to the international rules, each farmer has to be inspected annually. In Iran, there are no national certification bodies that may verify organic products officially[25] and farmers have to utilize international certification bodies. In Iran, where 80% of

farmers are smallholders, such a certification system is extremely expensive[26]. Some authors proposed establishing a national institute for the certification of organic products[25,27]. Mahdavi–Damghani[23] proposes a group certification system as an alternative way, in which farmers' groups consisting of a hundred to several thousand small-scale producers will be co-certified as a unit. Despite the differences amongst experts, there is consensus that certification is a barrier for the adoption of OA among Iranian farmers.

Market. Despite the global expansion of the market for organic products, it is still expanding very slowly in Iran[25,27–31], as in many developing countries. This is partly because organic products are more expensive than other products[32] and the majority of Iranian people cannot afford organic products[25,33]. Therefore, farmers are not sure whether they can sell their products in the national market[28]. Sari et al.[32] suggest that to overcome this challenge, the government should establish specific sites for selling organic products. This will decrease the costs of marketing for producers and therefore, the price of organic products. Furthermore, sufficient information about the benefits and standards of organic products is not available to both producers and customers[34]. Lastly, certification systems are considered by some authors as the root of many challenges for marketing organic products[23,24].

Knowledge and information. Lack of knowledge and information is reported by many researchers as a barrier to the adoption of OA in Iran[15,17,24,25,27,31,35]. Knowledge and information barriers relate specifically to market[25], and technical and financial issues[20]. Bello[26] believes that farmers in many developing countries lack technical information about farming practices, production and marketing methods, such as choosing products to grow, identifying different markets and distribution channels, competition strategies and market access.

Workload and costs. Previous studies have shown that organic farmers have greater labor needs compared with conventional farms[20,27]. Since many activities, such as weeding, are done manually in OA, there is a need to recruit more workers[20]. Additionally, OA can require more facilities for transport and storage, which are quite costly for farmers[25]. Moreover, the transition period to OA might be costly. Wossink and Kuminoff[36] consider that a farm in transition from conventional to organic needs to keep rigorous records for 3 years before being fully certified—an additional cost for farmers.

Influences on farmers' adoption of OA

Despite the barriers, there are factors that influence the adoption of OA practices by Iranian farmers. Findings are summarized in Table 2.

Experience. Some studies show that more experienced farmers with a higher level of informal knowledge are keener to learn about sustainable farming practices[15,18,39,40]. The traditional agriculture of Iran is a great deal like OA in many ways[8]. Mahmoudi et al.[5] believe that almost all practices and processes in the traditional agro-ecosystems of Iran are compatible with organic agriculture[5]. Therefore, years of experience in traditional agriculture can support farmers to appreciate and more easily adopt OA practices. Moreover, such an experience provides them with increased knowledge about the environment in which decisions for adopting OA must be made[44]. This seems to be a rather unique finding among developing countries.

Age. Age is positively correlated with experience in some studies[44]. Evidence shows that in Iran, older and more experienced farmers have a more positive attitude toward OA and IPM[18,40,43]. Although a few studies show that younger farmers are less risk adverse and may adopt organic practices sooner[10], some research has found that both groups of experienced and younger farmers who participate in extension programs (especially IPM/FSS) are more likely to adopt organic practices[16,40,43].

Gender. The term 'feminization of agriculture' is becoming a cliché that refers to the significant role that women play in the agricultural sector[45]. Some studies show that women are generally more willing to adopt organic practices[39,41]. OA supports gender equality because it creates meaningful work, offers economic opportunities for women, encourages biodiversity and traditional knowledge, and ensures equitable work standards[46]. According to Kang[47], women are the major stakeholders in OA because, over decades, the socio-economic and health statuses of women in farming communities have been adversely affected by conventional farming technologies and policies.

Education and knowledge. Both scientific and indigenous knowledge influences farmers' attitudes toward organic adoption. The positive impact of farmers' education on adoption was found by Omani and Chizari[38], Razzaghi-Borkhani et al.[16], and Sadati et al.[10]. Generally, educated farmers can acquire technical information more easily[44]. Farmers' education is identified as an influencing factor on organic adoption in other developing countries as well[48]. Behrad-Far and Farzanian[49] believe that in OA, modern knowledge is not in contradiction with traditional knowledge, but is complementary to it. Sofia et al.[50] explain that organic farming has been practiced since ancient times. As such, the values and principles of OA, including the principles of health, ecology, fairness and care[51] are in line with the traditional beliefs and values of farmers.

Income, yield and land area. Organic farmers can experience an increase in production costs because of the introduction of labor-intensive technologies. In addition, farmers face new costs related to certification and transportation[52]. Therefore, higher incomes might facilitate the adoption of OA by farmers. According to Kassie et al.[48], wealth affects adoption decisions, since wealthier farmers have greater access to resources and may be

Table 2. Main factors influencing farmers' adoption of OA in Iran.

		Factors												
		Farmers' characteristics												
Reference	Study focus	Experience	Age	Gender	Education	Knowledge	Communication	Attitude	Income	Yield	Cooperatives	Land area	Extension services	Gov. Support
Etehadi et al.[15]	IPM/Organic	+	+				+				+		+	+
Omani and Chizari[38]	OA				+	+			+	+				
Nemati and Azami[34]	IPM/Organic	+	+			+	+				+			
Moradi et al.[29]	IPM/Organic				+			+		+				+
Rezvanfar et al.[19]	OA								+	+			+	+
Ghorbani et al.[53]	OA		+									+	+	
Nazarian et al.[41]	IPM/Organic			+		+			+				+	
Razzaghi-Borkhani et al.[16]	IPM/Organic				+	+								
Mahboubi & Keshnizi[42]	OA							+						
Veisi et al.[18]	IPM/Organic					+			+			+		
Sadati et al.[10]	OA		–		+							+		
Ghorbani et al.[54]	OA	+			+				+	+				+
Ghane et al.[40]	IPM/Organic	+	+										+	
Dinpanah et al.[43]	IPM/Organic	+	+			+	+						+	
Sari et al.[32]	OA			+										+

+, Positive influence on adoption; –, negative influence on adoption.

better able to take risks. Similarly in Iran, some studies[10,38,41,53,54] show that farmers with higher incomes and larger farms are more likely to adopt OA. Yield is associated with income and land area in many small farms, and influences the adoption of OA[29,38]. These factors seem to be common around the world in regard to the adoption of OA[52,55] and other innovations[56].

Extension services and communication. Many studies[15,16,19,34,41,53] show that Iranian farmers' participation in extension programs will enhance their tendency to adopt organic farming practices. However, Behrad-Far and Farzanian[49] found that extension workers in Iran are generally not sufficiently capable of providing assistance with organic methods. To overcome this deficiency, FFS programs have recently been launched and are considered as the best training methods for farmers interested in organic agriculture[55].

Some studies[10,15,43] show that by increasing farmers' access to information and communication technologies, they are more likely to adopt organic practices. Organic farmers should develop their communication skills to increase their access to the information about the latest achievements in agriculture. Furthermore, technical assistance should take into account farmers' communication needs in Iran[15,43].

Farmers' membership in cooperatives. A few studies[15,57] show that farmers' membership or relationship with cooperatives increases their likelihood to adopt organic practices because they have better access to resources such as credit and extension services[58,59]. Moreover, when a cooperative adopts OA, it attempts to generate information that allows contracting, production and marketing planning, communication, and monitoring, in order to keep organic production costs at a low level[60]. This is in line with findings from Ethiopia[48] where the household's membership in farmers' organizations increased the likelihood of practicing organic techniques.

Government support. Studies[15,29,31,32,53,54,61] also show that governmental support can be very critical in generating positive attitudes in farmers to adopt organic practices. According to Mahmoudi et al.[62], it remains the responsibility of governments to change the attitude of farmers toward OA and encourage them to produce organic products. Such support can be provided in five areas, including organic food production at the farm level, processing and marketing organic foods, out-of-home consumption, consumer information and cross-cutting measures such as research and development[42]. The situation is the same in many developing Asian countries. According to Partap[7], the governments in these countries are not providing minimum incentives to farmers, NGOs, small and medium-sized enterprises involved in OA. In Ethiopia, Kassie et al.[48] found that poverty limits OA adoption. This means those policies which aim at alleviating poverty can positively affect adoption decisions.

Farmers' attitude. Some studies[19,63] confirm that farmers' attitudes toward organic farming influence their decision to adopt it. Iranian organic farmers strongly believe that organic production is harmless and healthier for both the environment and humans[40,62,64]. Moreover, the long-standing values and beliefs of farmers are in line with the values of sustainable practices of organic farming[39,63]. However, traditional beliefs that are in line with OA practices are declining. It appears that Iranian farmers now have a mix of traditional and modern values that drive them to adopt some organic practices, and reject those which are not productive or diminish their income. For example, a study by Bagheri and Shahpasand[63] on potato farmers' attitude toward sustainable and organic agricultural practices shows that some farmers had a negative attitude toward using fewer fertilizers and pesticides, while their attitude toward some methods of securing sustainability, such as soil and water conservation and crop rotation, for instance, were positive. These same attitudes can be found in other developing countries[65].

Discussion and Conclusion

There is growing evidence that increased adoption of organic farming can offer numerous environmental, social and financial benefits, and lead to an alternative way to sustainability in agriculture[2,66,67]. The results of this study show that for Iranian farmers, there are some main challenges that slow down the process of adopting OA. These barriers include challenges in certification, market, access to knowledge and information, labor and costs. These barriers exist in many developing countries[68]. Among them, certification seems to be the most serious problem in Iran, in comparison to other developing countries, due to Iran's limited international communications and lack of national certification bodies.

In spite of these barriers, there are some factors that influence Iranian farmers' decision to adopt OA practices. Experience is one factor that influences farmers to adopt OA. Since most Iranian farmers are older and experienced[15,57], such attributes can be regarded as an opportunity for the promotion of OA. Gender can also influence OA adoption, and studies found that women are better adopters of OA[32,41]. Knowledge from both types of formal (education) and informal (indigenous) sources also has a positive effect on the adoption of OA. Income, land area and productivity have positive impacts on farmers' adoption as well. Extension services are important in the promotion of OA, especially IPM/FFS programs that apply participatory methods for disseminating OA. Findings show that those Iranian farmers more likely to adopt OA are those who have a more positive attitude toward OA; have access to communication technologies; are members of cooperatives; and are farmers supported by the government. Similar findings are reported in other developing countries[26,48,69,70].

Implications for current practices on OA adoption

Taking the findings of the discussed case studies into consideration, we make four recommendations to increase the adoption of OA in Iran: (a) appreciating the Iranian farmers' role in the process of adoption, (b) rethinking extension programs, (c) realization of the facilitation role of women; and (d) appropriate governmental support.

(a) Appreciating the Iranian farmers' role in the process of adoption. Most factors that drive farmers to adopt OA are directly related to personal attributes of farmers (e.g., experience, age, gender, education, knowledge and attitude). However, the development of organic farming is led by the Iranian government through top-down processes[15] that often disregard farmers' concerns and their characteristics. The critical issue is that in many extension programs at the rural level[36], wealthy farmers are the focus of the programs, whereas poor and small-scale farmers are often ignored.

(b) Rethinking extension programs. Providing extension services to increase organic farmers' yield and supply natural inputs are necessary[54]. Among other extension initiatives, FFS programs have been reported as the most successful in facilitating the adoption of IPM technologies in Iran[37]. However, some studies show the unsatisfactory impacts of FFS programs, maintaining that they have been mainly successful in changing farmers' attitudes and not their behavior. Other studies show that they could not improve the farmers' collaboration over the long term. For example, a study by Etehadi et al.[15] shows that, from farmers' point of view, FFS has been very effective in providing relevant information, but not linking farmers, researchers and extension agents to each other over the long term, because the farmers' collaboration and linkages with research and extension are limited to the project duration, and collapse once the project ends [14].

(c) Realization of rural women's facilitation role. It is important to understand that women are not merely the adopters of OA, but can also be important facilitators and promoters of organic practices among farmers, processors of agricultural products and their family. According to Partap[7], all over Asia, women are taking a leading role in OA development—as farmers, as consumers, or as the organizers of the organic sector. For instance, in Thailand and Malaysia, many of the pioneer traders of organic products are women. In India, the organic movement receives much support and leadership from women self-help groups, NGOs and individual entrepreneurs. Similarly in Iran, rural women are generally more willing to adopt organic practices and are the main customers of organic products[32]. However, support and extension services for rural women are very limited. The study of Etehadi et al.[15] on the effectiveness of IPM/FFS sites showed that only 11% of the participants were rural women. Men were also more satisfied by the IPM/FFS sites, which were originally planned for them. The main conclusion is that rural women's access to information and credit for organic production should be enhanced and an awareness of the importance of organic foods among rural women needs to be emphasized.

(d) Appropriate governmental support. In the past, OA has been adopted without the support of governments and agricultural extension agencies in Iran. Especially in the early stages, farmers applied organic practices without any professional backup or infrastructure[71]. Today, the situation is different. Modern agriculture has resulted in the increased use of chemical inputs, causing adverse impacts on human health and the environment[15]. Therefore, a critical role of the government is envisaged. According to Partap[7], governments should consider providing direct incentives, rather than subsidies, to organic farmers. Moreover, there is a need to allocate resources and expertise to establish private institutions/agencies that can facilitate the adoption of OA. Such institutions can be managed by pioneer organic growers. Esmaieli[72] proposes that organic farmers should receive specific insurance services as a support from the government. Such insurance should cover the first 3 years of the transitional period, yield losses as a result of diseases, and market failure, among others.

Abdollahi[73] believes that government supports should include subsidies, long-term loans, the establishment of organic farmers' organizations and facilitating farmers' access to information about technical issues of OA and marketing. Additionally, Yaghubi and Naseri[74] suggest that the government can ease the access of organic farmers to information through holding workshops and exhibitions on OA. The government can also support organic farmers in the domestic market by purchasing their products in advance before harvest. The policies for developing organic farming should be formulated in a way that allows a bottom-up approach[75].

Implications for future research

The recommendations proposed in this paper are expected to improve the rate of the OA adoption. Further research is needed to address how best to bring these mechanisms into practice. For instance, there is a need to assess the governmental supports for organic farming at the farm level. Moreover, the role of rural women, and their challenges and opportunities in adopting and promoting organic farming, should be studied. The effectiveness of existing extension methods for fostering OA should be assessed on the bases of 'region-case' and 'crop-case'. Finally, future studies could address the weight of the different applied criteria in this study to come up with further insights into the decision making process—why farmers decide for or against the adoption of organic agriculture.

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Critical agrarianism

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Abstract

This paper develops the concept of 'critical agrarianism' to describe and advance the pursuit of land-based work as a means of realizing social justice and environmental sustainability. Encouraging new agrarianism to more carefully scrutinize its agenda, critical agrarianism celebrates the promise of a close working relationship with the natural world while insisting that a return to the land—*per se*—is insufficient. In the practice of linking people and land, past and present, critical agrarianism continually questions and reshapes the very category of agrarian, toward a more equitable and enduring prosperity. I revisit both canonical agrarian writing and its critics, pulling out 'back-pocket tools' that can keep critical agrarians on track in building our alternative futures. I then offer several case studies of critical agrarianism in practice, encouraging a move beyond idealized models of agrarian ties, toward an empirical account of who has actually been doing the work to put food on the table. Noting the historical gap between working the landscape and having a property or citizenship right, I call for an agrarianism in which practices—not land title—are the basis of material and social community. Furthermore, I suggest that agrarianism must extend its web outward rather than inward, forging connections to the work of land tenure reform, education, community development, immigrant advocacy and trade policy. To be a critical agrarian is not to preserve fixed social-natural ties, but rather to practice a powerfully open and dialogical engagement with the world and one another.

Key words: agrarianism, sustainable agriculture, agricultural labor, agrarian political economy

Introduction

Fifty-five hundred West Silver Spring Drive lies at the heart of inner-city Milwaukee; Henry County, Kentucky amid a quiet mix of farms and exurban homes. They are, you might say, on opposite sides of history. Written in the contrast of these two landscapes is the great tragedy of the American story: the continual separation of prosperity from those who have labored to create it. In both places, people have spent decades suppressing this tragedy; and when memories arise, they clash. Yet two men—one white Kentuckian, one black Milwaukeean—have begun telling a remarkably similar tale about the value of their Southern agrarian heritage. A thoughtful return to the land, they suggest, may hold the keys to a more just prosperity.

Urban farmer Will Allen and homesteader poet Wendell Berry both draw on agrarianism, a philosophical tradition with deep roots in Western history. As Laura Sayre writes, agrarianism is 'the idea that farmers make the best citizens, that they possess an intrinsic virtue based on their close working relationship with the natural world and their independence from corporate and consumer culture.'[1] The history of this idea is far from innocent; and yet, Allen and Berry have good reason to find hope in it. In this article, I take stock of where agrarianism has been, what its heterogeneous potentials are, and how it might be mobilized toward a more sustainable, equitable future.

I find myself writing this essay because I have so often felt torn: between the student farm and the seminar, the compost pile and the protest. I am convinced that much can be accomplished by hands in dirt, and I have been inspired by those who effect transformation through the way they connect land and people. I also deeply respect those who have come to critical analyses of agrarian relations through years of dedicated study, and who put themselves on the line to raise awareness of hidden violence and exploitation. Too often, these two deeply felt efforts are perceived as competing agendas: critics feel pressed to dismiss student farmers as avoiding structural problems, while student farmers are taught that critics do not do anything useful. And yet, I am surrounded by critical thinkers who have their hands in the dirt *and* their hearts in the struggle, who make things in a way that makes change too. What I am reaching for here is a language to talk about these mentors and comrades and

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recognize their work. I hope this is a language that might empower those who have felt torn like I do, those who do not want to choose sides.

I am calling that language *critical agrarianism*, and this is what I mean to suggest with this term: in the practice of linking people and land, past and present, critical agrarians continually question and reshape the very category of agrarian, toward a more just and sustainable future. They push critique beyond being critical *of* agrarianism. Instead of seeing agrarianism as inevitably constrained by a narrow history, they ask what it has become or could be. Meanwhile, they push agrarian thinking beyond taken-for-granted assumptions about what exactly is or can be accomplished through tying people to land, insisting that we will have to continually make and remake these relations. Thankfully, thoughtful people have been pushing in these directions for a long time.

Old White Men and Property

To take a page from the critical handbook, it helps to know where ideas come from, the context in which they have developed. Histories of American agrarianism generally begin with John Locke's *Second Treatise on Civil Government*[2] and Thomas Jefferson's *Notes from the State of Virginia*[3], political philosophies couched in the discourse of romantic poets. Such histories often proceed to J. Hector St. John de Crevecoeur's testimonial, *Letters from an American Farmer*[4]. All three merit a close read.

Locke's 'Of Property,' the fifth section of his *Second Treatise*, develops a labor theory of value on the basis of Christian theology, natural law theory and the institution of private property. 'Whatsoever then he removes out of the state that nature hath provided, and left it in, he hath mixed his labour with, and joined to it something that is his own, and thereby makes it his property,' he writes. For Locke, the improvement of land through agriculture is mankind's God-given duty. Thus, the institution of private property inevitably arises (through the mixing of labor with the soil), and should be understood as natural. Agrarian rights, however, come with agrarian responsibilities. Locke emphasizes that individuals are entitled only to what they can use; and that the rest must be left for others. Locke's signal contribution to agrarianism, then, is a Biblically derived agrarian exceptionalism. Since it involves mixing one's labor with the soil, he holds, farming is a spiritually and materially superior form of work, the root of both personal wealth and personal salvation.

American President Thomas Jefferson, a farmer himself, would expand poetically on this agrarian exceptionalism, cementing in the American consciousness an image of the yeoman farmer as the bedrock of the nation's morality and democracy. 'Those who labour in the earth are the chosen people of God, if ever he had a chosen people, whose breasts he has made his peculiar deposit for substantial and genuine virtue,' Jefferson writes in his *Notes on the State of Virginia*, in the midst of the Revolutionary War. For Jefferson, as for Locke, smallholder farming is both an individual moral necessity and a national political imperative. Working directly with nature to supply one's subsistence fulfills man's God-given purpose and maintains proper Christian values, while distributing property among many smallholders ensures a population of democratic subjects.

The year after Jefferson wrote these words, J. Hector St. John de Crevecoeur published *Letters from an American Farmer*, offering first-hand testimony of the emergent nation's democratic agrarian society. 'Here we have in some measure regained the ancient dignity of our species,' de Crevecoeur boasts. 'Our laws are simple and just, we are a race of cultivators, our cultivation is unrestrained, and therefore everything is prosperous and flourishing.' The *American Farmer*'s romantic, closer-to-nature vision proceeds to a Lockean justification of private property as the natural reward for transforming 'formerly rude soil' into a 'pleasant farm.' Labor and soil, converted into property, beget political standing, expressed as citizenship. For de Crevecoeur, 'possession of the soil' is foundational to who we are as Americans. It not only feeds and clothes us, but has also 'established all our rights; on it is founded our rank, our freedom, our power as citizens, our importance as inhabitants of such a district.'

A number of agrarian themes emerge from de Crevecoeur's text: ecological, political and personal. His principal focus, however, is on the material and spiritual benefits of decentralizing land tenure. 'Europe contains hardly any other distinctions but lords and tenants,' he writes. 'This fair country alone [the United States] is settled by freeholders, the possessors of the soil they cultivate, members of the government they obey, and the framers of their own laws, by means of their representatives.' Whether de Crevecoeur's promise of radical democracy was being fulfilled at the time is an easily contestable matter (a point critical agrarians must —and do—take up). Yet, in this Jeffersonian rhetoric lies an important kernel of agrarian political thought: the conviction that decentralized, distributed management benefits both 'nature' and 'culture.' As later agrarian thinkers moved beyond the project of nation building to address different concerns, this idea remained, rearticulated.

Back to the Land

Among the first to revive and thoroughly revise this idea were four prominent agrarian conservationists: Aldo Leopold, Wendell Berry, Wes Jackson and Fred Kirschenmann. While 18th-century agrarianism had offered political prescriptions for prosperity, these

20th-century writers broadcast a message of moral and environmental crisis. The march of industrial progress, the conservationists warned, threatened the natural basis of the democratic citizenship promised by the nation's agrarian founding fathers. In order to preserve this virtue, they wrote, we must preserve our farmland, our farming heritage and, most especially, our farmers. These authors fought against industrialism on the one hand and wilderness conservation (a prominent contemporary critique of industrialism) on the other. Rather than calling for the unpeopled wilds celebrated by Thoreau and Muir, agrarian conservationists argued that the natural landscape benefitted from good human stewardship—perhaps even needed it. The most critical endangered species to save, they insisted, was the small-scale farmer, threatened by the industrial forces of concentration and large-scale mechanization. Leopold's answer to the industrial crisis was the land ethic[5]: a strong moral bond that compelled the smallholder to care for his property such that it would thrive for generations to come. Only by keeping such landholders on their working landscapes, Leopold wrote, could society cultivate this ethic—the true guarantor of lasting environmental and social prosperity.

The battle against industrialism portrayed by Leopold had been the 'farmer's problem' since at least the late 19th century, when rural Populist movements organized nationwide cooperative networks and supported a serious presidential candidate. Yet, when agrarianism roared back in the late 1960s and early 1970s, it found a substantial new constituency for its critique of corporate concentration and monopoly power. Counterculturists galvanized by the Vietnam War and environmentalists awakened by Rachel Carson's *Silent Spring* stood ready to join the battle against 'agribusiness,' now understood as part of the military–industrial complex and a first-rate polluter. Thus, the new generation of agrarian writers reached well beyond 'farm people.' Berry[6,7], Jackson[8] and Kirschenmann[9] cast agrarianism in both moral and environmental terms as a simpler life, free of the social and environmental violence that so horrified 1960s youth. Thousands of young people, inspired by this promise, moved 'back to the land,' in search of an agrarian paradise. While the radical counterculture faded somewhat in the face of the Reagan Revolution, agrarian writing resurged in response to the most serious catastrophe of agrarian concentration since the Great Depression: the mid-1980s farm crisis. As great swaths of the rural population lost their farms and moved to cities, leaving behind towns too small to support schools, churches and corner stores, Berry[10,11], Jackson[12,13] and Kirschenmann[9] again called for preservation of the agrarian basis of American citizenship.

These back-to-the-land narratives share several features, reviving the themes of de Crevecoeur. After growing up in strongly agrarian, multi-generational communities they cannot yet appreciate, the protagonist-authors leave home to pursue some version of modern prosperity. Disillusioned with the emptiness of urban life, they return home, only to find crisis: many people have left, and those who remain are struggling to make a living and hold onto their land. The project of the 'homecomer'[12], then, is to recover the heritage of self-sufficient rural lifeways, often from childhood memories of wisdom imparted by parents and grandparents. Such wisdom forms the foundation for rebuilding a sustainably prosperous community. While this conservatism fosters a healthy skepticism about the merits of various forms of 'progress' and has been a powerful lever of resistance against corporate and colonial exploitation, it runs the risk of becoming a rather broad-spectrum critique, which stymies democratic dynamism and desirable forms of change. If our only agrarian agenda is preservation, we are stuck with a denial that urban modernity can be generative (not just degenerate) and a defense of the 19th-century land tenure system (in which only elite white men owned property).

Agrarian (Pipe) Dreams?

Given these dangers, then, it is worthwhile to sharpen our critical tools, to make clear how agrarian discourse gets linked to inequitable land tenure and overly narrow political economic visions, to reveal these associations as contingent, and to empower ourselves to disassemble them. Rather than attempt an exhaustive survey of the growing critical literature on agrarianism, I turn to a few key works that make the points I have found most useful to keep in my back pocket.

Literary scholar Raymond Williams was one of my first such teachers. I read *The Country and the City*[14] during my first semester in graduate school. Combing through hundreds of years of British agrarian writing, Williams pieces together a cautionary tale about moralities based on the contrast between 'rural' and 'urban.' He finds that unpalatable forms of 'progress' transform *both* country and city. Rather than fleeing cities in the hope of escaping social and environmental changes we do not like, Williams suggests, we should recognize that such changes are processes that interrelate urban and rural. We need to face them head on. Happily, the agrarian movement has incorporated much of this critique, moving from the back-to-the-land utopias of the 1960s to today's urban agriculture coalitions. Such coalitions—epitomized by the rise of food policy councils—engage directly with the social processes to which Williams refers, taking on the issues of housing, employment and education as well as growing food[15,16].

Also in my back pocket are the lessons of the Dust Bowl, first introduced to me by my grandmother, who lived through its hardships on a farm in Western Nebraska. American environmental historian Donald Worster[17] thoughtfully chronicles this tragedy, warning that agrarian discourse can be used to convince people to

recklessly produce more and more. He finds that the Dust Bowl arose as agrarian ideals formed a thick cultural web around the economic imperatives of capitalism, fostering an unsustainable growth economy poorly suited to fragile prairie ecology. Taking this lesson to heart, then, we critical agrarians should not sign up for just any farm work party. It is not enough for all of us to labor; all of us must also take part in a democratic conversation about the way our labor is structured and what goals it should serve.

To this point, the third critical tool in my back pocket makes clear that just agrarian prosperity can never be achieved through individual efforts or self-sufficiency alone. Some of the work we need to do can only be done collectively. Thus, when geographer Julie Guthman[18] goes 'back to the land,' she investigates not its environmental or moral merit, but the implications of its financial worth. Her research reminds us that even the most well-meaning agrarian practitioners confront the constraints of a financialized land market that does not share their values. Surveying organic growers in California, Guthman finds their dreams powerfully constrained by the reality of their rents and their debt. Even though many of these organic growers personally value environmental and social goods, Guthman discovers, the value of their land is based on market-determined 'highest and best use.' In order to avoid bankruptcy, then, they are forced into compromises—like monocropped organic strawberries—that allow them to earn high premiums while fulfilling some of their agrarian ambitions. Guthman's work demonstrates why critical agrarianism cannot run from the key issues of land tenure and debt load (a point made also by Wendell Berry). Tenuous and expensive land tenure severely limits most wide-eyed agrarians, while debt often eviscerates the supposed virtues of fee simple farm ownership, even among seemingly secure white male family farmers. To make the changes we wish to see, we critical agrarians will need alternative land-tenure models that explicitly value public environmental and social goods. A critical mass of private property owners with a strong land ethic can never be enough. As Jefferson himself said, 'while the farmer holds title to the land, actually it belongs to all the people, because civilization itself rests upon the soil.'

While such challenges cut across color lines, my fourth back-pocket tool acknowledges a particularly sobering critique of agrarianism: race. As Rachel Slocum[19] has recently noted, agrarian projects can reinforce white privilege by ignoring the racial history of US land policy and reproducing structural and cultural 'whiteness.' Patricia Allen and Carolyn Sachs[20] make a similar argument. While the loss of white land in the mid-1980s was met with cries of foul, they observe, New Agrarians hardly noticed the 94% decline of black farm ownership over the course of the 20th century. Meanwhile, as far back as W.E.B. DuBois, African–American leaders have rightfully been quite critical of agrarianism, seeing it associated with lynch mobs more than with freedom and democracy. Race—along with the land tenure—is one of the dimensions along which the concept must be thoroughly remade if it is to empower that just prosperity we critical agrarians are after.

To add a fifth and related back-pocket reminder, agrarianism needs to be attentive to gender inequity. As Sachs notes, 'in the U.S. food and agriculture system, including the majority of family farms, men control land, capital, and women's labor[21], while women contribute significantly to the sector's profitability as wage workers and as unpaid labor on family farms.' Nipping gender inequities in the bud means asking what types of work we celebrate as 'agrarian,' who we label 'the farmer,' who we teach to use the tractor, and who is expected to do the unromanticized work of reproducing the agrarian household—that is, the laundry, the dishes, the taxes and the wage work that provides health insurance. We should not build our agrarian dreams on the backs of exploited and marginalized women.

Toward a Critical Agrarianism

Such critiques remind us that a return to the land—*per se*—is not necessarily a good thing. They provide a set of handy back-pocket tools to keep us critical agrarians on course as we build our alternative futures. Yet in veering from the blueprint of wholesale agrarian romanticism, we must not swing too far toward wholesale agrarian cynicism. Paying attention to history does not require us to see it as inevitably constraining. Rather, embracing the mythological quality of agrarianism that Williams so astutely identifies, we might recognize this storytelling opportunity as a powerful opening. Agrarianism is subject to multiple articulations, even radical retellings. It need not be co-constituted with a defense of 19th-century American property systems and power structures. Conservative political–economic stowaways may occupy the vessel of agrarianism, but they are not necessary to float its philosophy and politics. Indeed, careful attention to the agrarian stories we tell might well be one of the more effective ways of transforming relationships among land, people and memory.

My call for a critical agrarianism is thus intended to be generative and creative. It is a call for new forms of 'linking up' past and present, people and land. It is a call for linkages both more honest and better aligned with truly just and sustainable futures. Such a linking up begins with practitioners like Allen and Berry. It begins with efforts and histories already in progress but left out of mainstream agrarian discourse. Yet innovative members of the critical community—particularly those who have substantively engaged agrarian movements themselves—have something to offer too. Lawyer and critical legal scholar Eric Freyfogle develops a reformulation of agrarianism that highlights the key role of land tenure

and suggests ways in which private property rights might be constrained in the name of community and public goods[22]. Agricultural and environmental philosopher Paul Thompson argues that the agrarian project and the project of sustainability gain focus when viewed through each other's lenses. This engagement, he holds, pushes agrarianism toward a more humble ecological stance[23]. Theologian and philosopher Norman Wirzba reorients agrarianism's gaze from past to future, declaring that 'its full realization still awaits us,' and calling on agrarian communities to eradicate trappings of oppression that continue to haunt the 'bonds of relationship'[24]. While the writings of Freyfogle, Thompson and Wirzba are relatively well known to readers of Berry and Leopold, however, two other conceptual tools useful to critical agrarians are less commonly associated with the lineage of agrarian thought. These arguments—Melanie Dupuis and David Goodman's 'reflexive localism'[25] and Hannah Wittman's 'agrarian citizenship'[26]—both help clarify what critical agrarianism looks like in practice.

Reflexivity and Agrarian Citizenship

Dupuis and Goodman[25] do not deal directly with agrarianism, but with a parallel concept also much maligned of late by social critics: localism. While local food systems are not by definition more just or sustainable, they acknowledge, a reflexive approach to them might well reap rewards. In turning to the local, Dupuis and Goodman suggest, we have identified a key pivot, a terrain to work on, a point of intervention. The next challenge is to pay close attention to the nature of such interventions. Instead of declaring 'let's have a local food system,' Dupuis and Goodman propose, we can ask 'what kind of local food system should we have?' Critical agrarians might constructively make the same move. Beyond the pronouncement, 'let's have *stronger* ties between people and land,' we can turn to the question of 'what *kind*s of ties between which people and what land?' What are we exchanging? With whom? What are the boundaries of our reciprocal communities? With whom do we share? Whom do we leave out? And whom do we leave less resilient?

If Dupuis and Goodman help us conceive critical agrarianism as fundamentally reflexive, Wittman[26] helps us see agrarianism from the perspective of the landless and marginalized, rather than the propertied and privileged. Brazil's *Movimento dos trabalhadores Sem Terra* (the MST or Landless Workers Movement), she writes, offers an articulation of agrarianism that activists in the Global North ought to heed:

> By contesting the equation of property with citizenship, agrarian citizenship, as expressed and enacted by members of the MST, goes beyond traditional or liberal conceptions of rights linked to individual property, production, or possession. Instead, it foregrounds new collective roles and rights for rural dwellers .... These are designed to ensure not only the economic survival and political demarginalization of the rural poor but also a broader conception of land stewardship as a social relation that involves all members of society. (p. 121)

Interestingly, personal connection of the sort encouraged by agrarians such as Leopold and Berry underpins this political struggle against the structure of land tenure in Brazil. The MST settlers Wittman interviewed 'suggested that an important factor mediating their ability to combine political activities with agricultural settlement practices and to survive as both small producers and political actors in the face of ongoing challenges to small-scale production in Brazil was the level of personal transformation that they had experienced as a result of the ongoing practical struggle to stay on the land.' One activist explained: 'if the body stops, the consciousness stops, it gets stagnant.'

Wittman's study thus suggests that heartfelt affective ties between people and land may prove central to the success of broader social struggles, because they reinforce (and are reinforced by) affective ties between people and people[27]. Revising the Jeffersonian vision of multiple one-to-one tethers between farmer and landscape, such an agrarianism configures a dense socio-ecological network of community/human relations that is, in turn, tightly bound to the land. Thus, the MST's version of citizenship echoes Locke's insistence that agrarian rights be accompanied by agrarian responsibilities. The movement calls for 'using land in accordance with a social function perspective—providing food for the nation, respecting labour rights and the environment, and providing rural space for political action.' Moreover, the MST's agrarian citizenship challenges the absolutism of structuralist agrarian cynics as much as the absolutism of moralist agrarian romantics. Contesting the assumption that 'access to land alone will lead to the development of new forms of citizenship and rights,' MST agrarians insist that active agrarian citizenship must be developed through the everyday practices of people on the land, in their intertwined production and political activities. This includes a commitment to agroecological methods of production that sustain resources for future agrarian citizens.

Who is the Farmer?

Wittman's account of the MST illustrates what critical agrarianism looks like on the ground: how it is that agrarian practitioners can continually question and reshape the very category of agrarian, toward a more just and sustainable future. The MST settlers quoted in Wittman's article have clearly done this, contesting both the primacy of private property rights that dominates

Brazil's agrarian economy *and* the most prominent discourse of resistance, which focuses solely on access to land, rather than the details of everyday agrarian practices. The MST thus engages agrarian struggle while redefining what responsible agrarianism means. If writing the MST into an account of agrarianism is one promising move, where else might we critical agrarians look for inspiration?

One starting point for such an agrarianism is an empirical account of who has actually been doing the work to put food on the table. As Kloppenburg[28] proposes, we critical agrarians might reconceive the basis of agrarianism as the embodied knowledge based in this labor. Since those who work the land are not always (or even usually) those who own it[20,29–34], this shifts the discourse of agrarianism from one of property rights and conservation to one of resource access and social transformation. In the next section, I consider three American agrarian traditions in which land titles have not followed from land ethics. These traditions are based on the experiences of Latino farmworkers, Japanese–American communal farmers and sharecroppers, and African–American descendants of slaves and sharecroppers. By highlighting the extraordinary struggles of non-landowners to extend agrarian care, I hope to demonstrate that agrarianism has as much to gain by bringing land back to people as by bringing people back to the land.

Farmworker Agrarianism

Farmworker agrarianism complicates the basis of the typical agrarian narrative in two fundamental ways: the agrarian protagonist does not own the land he or she tends, and industrialization has not distanced the agrarian narrator from land-based labor. Rather, industrial agriculture works to keep the farmworker agrarian on the land, intensifying the labor process to the point of injury and even death, while making ownership nearly impossible. Amazingly, however, farmworker agrarianism is a robust movement: one which has led many Salinas Valley families to carefully tend subsistence gardens after working hours, enroll in programs to transition to organic farm ownership[35], and engage in one of the most effective anti-pesticide campaigns ever mounted[31]. Such agrarianism-from-below is not only possible, but uniquely effective in addressing the forces that give rise to the agrarian critique in the first place.

This critical agrarian potential is realized poetically in Elva Treviño Hart's *Barefoot Heart*[36], which bears interesting similarities to more canonical agrarian texts such as Wes Jackson's *Becoming Native to this Place*[12] or Wendell Berry's *Unsettling of America*[7]. A professional woman recalling her youth as a migrant farmworker, Treviño Hart mirrors Berry and Jackson in longing for her agrarian childhood. She feels a sense of loss in the city and notices nature in the lovingly detailed manner with which de Crevecoeur describes his bees:

> I found things in the dirt to be interested in. No toys; no one even thought of toys. An adult looking at the scene would have seen a child with not one thing to occupy her mind. But I found a thousand things to interest me: The dragonflies, the red-winged blackbirds with their shiny black bodies, brilliant red wings, and hopeful songs. No two leaves were the same on the trees at the edge of the field. The wind sighed like my mother as it blew through the leaves. The clouds endlessly changed and moved (p. 41).

Yet the message of Treviño Hart's memory is not nostalgia for a simpler, gentler past. Even her metaphors gesture to her mother's sighs, her father's pain. Treviño Hart's connection to and care for land persists in spite of the violent way in which her family is continually uprooted, not because they enjoy a secure foothold. Sometimes this care becomes frustration, as when her father's herculean, deeply felt stewardship of the family avocado tree cannot persuade it to produce fruit in the northern latitude to which fieldwork has forced him to relocate:

> My mother smuggled an avocado pit home in her handkerchief ... My father planted this tiny piece of his homeland and tended it like a first born son .... Avocado trees don't bear fruit for seven to eleven years from the date of planting. But my father was undaunted. He just kept taking care of it .... It bore five huge, delicious avocados .... It never bore fruit again. After five more years of mammoth cave-like plastic coverings for the tree ... my father let it freeze. And then he cut it down, bitterly resigned to his separation from Villaldama (p. 107–8).

Moreover, Treviño Hart's eventual homecoming does not find people gone (as Jackson's does), but still being exploited. The building she lived in has indeed been destroyed, but not because a conglomerate gobbled up the property. Rather, the government declared the outbuilding her family once called home 'unfit for human habitation.' Coming 'home' to a place that never acknowledged her as a full citizen, Treviño Hart finds her agrarian community still on the land, but structurally constrained from realizing its agrarian visions. Her agrarianism calls not for a return to a more innocent past, but for a restructuring of rights and belonging in the countryside.

Tomás Rivera's 'La Cosecha,'[37] a fictional story based on Rivera's own childhood as a farmworker, likewise illustrates how a strong, Leopoldian land ethic might thrive in the absence of property ownership. The story follows farmworker Don Trine—not a man with free time on his hands or an embarrassment of resources—as he makes his daily afternoon pilgrimage to stick his hand in the earth and feel the changing of the seasons. Harvest is almost over. Workers are preparing to travel to Texas for the winter. And yet, Don Trine tends a reciprocal, sacramental relationship with land he does not own, to which he may never be able to return. A young boy who

witnesses and replicates Don Trine's ritual explains, through Rivera's narrator, 'What he experienced and what he never forgot was feeling the earth move, feeling the earth grasp his fingers and even caressing them.'

Japanese-American Agrarianism

Japanese-American agrarianism similarly exemplifies the presence of a strong land ethic despite structural barriers to property ownership. Japanese farmers were barred from owning land in California by the 1913 Alien Land Law, which was strengthened in 1920 to prohibit leasing as well. Nonetheless, a surprising number of Japanese-American farmers persisted in the face of the discriminatory legislation, accepting higher rents and other disadvantages of their second-class citizenship and devising clever legal workarounds. As of 1925, almost half the Japanese population in California worked as small farmers. A far more serious setback to Japanese-American farming, however, arrived in 1942, in the form of the World War II policy of internment[38]. Americans of Japanese descent were forced to resettle in one of ten camps, leaving behind homes, farms and businesses, to which most were unable to return. Incredibly, many Japanese-Americans maintained strong agrarian traditions both during and after World War II: caring for internment camp gardens and becoming sharecroppers after the war. In one particularly striking case, internees hired caretakers to ensure that a collectively farmed agrarian community would survive beyond internment[31].

Valerie Matsumoto[31] tells the story of this exceptional community, the Cortez Colony. Founded in 1919 by Abiko Kyutaro, the colony was self-consciously designed both to foster Jeffersonian agrarian virtues in new immigrants *and* to assert belonging in the face of overt racism and legal challenges to citizenship. As such, it was connected to several other Abiko-founded businesses, including a widely read newspaper, all of which aimed to protect Japanese-Americans' rights, explore new fields of urban and rural enterprise, and facilitate further immigration. Thus, while promoting responsible landedness in much the same terms as traditional agrarians, Cortez was hardly the stuff of defensive or nativist localism. Indeed, one of its primary aims was to successfully and materially contest such sentiments in rural California. Taking Locke at face value, the colony promoted agrarianism as a practice, conceiving it (much like the MST does) as a form of citizenship earned, not given.

Moreover, while aiming to cultivate personal connections and responsibility to the land (and the United States), Cortez was fundamentally collectivist, rather than individual. The colony mobilized agrarian ties as a means of communally overcoming the strictures of the Alien Land Laws (through collective ownership) and internment (by pooling resources and establishing a governance structure, then negotiating a trusteeship agreement with white allies). Ties forged through deeply personal agrarian relations were mobilized to successfully resist racist attempts to economically and politically purge Japanese 'aliens' from the social body. As Matsumoto explains:

> The combined efforts of the three Japanese-American cooperative associations—the Cortez Growers Association (CGA), the Livingston Fruit Growers Exchange, and the Livingston Fruit Growers—enabled the Issei and Nisei to maintain not only economic stability but also a remarkable degree of social cohesion during the evacuation. The growers' associations ensured that the Cortez Japanese-Americans would have homes to return to at the end of the war (p. 89).

Historians marvel at the great care with which Japanese-Americans tended the gardens and farms of assembly centers and internment camps, and the Cortez colonists were no exception. As Matsumoto notes, using the term 'victory garden' without a hint of irony, 'As soon as their shock abated, the Japanese-Americans set to work to improve their bleak surroundings ... victory gardens began to appear around the barracks.'

Yet, the most incredible expression of the Cortez colonists' agrarian care is perhaps the work they undertook when they returned from these camps to resume farming in their own 'home place.' They were not yet able to move back onto land still legally rented to white tenants. Their move back from internment was scheduled as hastily and heavy-handedly as their move there had been, making it impossible to plan ahead for the season. Undaunted, the colonists lived in rented army tents, cooked their meals outside, and worked alongside their much less-skilled white tenants throughout the grape harvest (racial hierarchies and anxieties still very much intact) before returning to their homes the following season. Despite a lifetime of such bitter agrarian memories, moreover, the older generation of Cortez colonists continued to express strongly felt love for their life on the land when Matsumoto arrived in the 1980s to record oral histories. Like Treviño Hart, the Cortez colonists held onto personal agrarian ties in spite of structural barriers and forced mobility—and in fact, mobilized their agrarianism to contest dominant political economies.

Miriam Wells[39] describes another exceptional instance of California Japanese-American agrarianism: Central Coast strawberry production. Unique among Central Valley strawberry growers, she finds, Japanese-American strawberry sharecroppers in the Pajaro Valley invested the most per acre, had the longest tenure on particular plots, systematically experimented with their farming systems, paid the highest and most stable wages, and used core workers for as many tasks as possible. Building long-term relationships with their workers (most of whom were Mexican), they planted crops with short-lived labor demand to provide work during berry lulls. Some adjusted schedules so that workers could move onto the apple harvest or draw unemployment when strawberry work ended. One grower interviewed by Wells even developed a

profit-sharing pension plan for workers who stayed with him for at least 7 years, speaking of their 'symbiotic relationship.' Clearly Berry-esque in their commitment to land and community, these growers were nonetheless leasers—not owners—of their land. As Wells' analysis demonstrates, these renters were far more the agrarian guardians of this land than those who held its title.

For the Japanese-American Cortez colonists and strawberry sharecroppers, then, agrarianism was a means of contesting, not reinforcing, structural racism. Challenging naturalistic framings of agrarian belonging, they emphasized responsibility to community in practice over fixed blood-and-soil bonds, insisting that Japanese-Americans too had a 'home place' in the California countryside.

African-American Agrarianism

Among those who have established critical agrarian traditions, then, are several 'imported colonial subjects'[33] whose experiences have been characterized as forms of slavery: Latino farmworkers forced by trade assaults and immigration policy into economic subjugation; Japanese internees imprisoned against their will and dispossessed of most of their property. That the term *slavery* is used by activists to drive home the seriousness of such exploitation, however, necessarily points us critical agrarians to the plantation history of the American South. African-American agrarianism, seemingly a contradiction in terms; has become one of our country's most challenging and truly transformative movements. It not only remakes the category agrarian, but turns it completely on its head.

Two prominent African-American led urban agrarian projects, Chicago's Healthy Food Hub and Milwaukee's Growing Power, illustrate the significance of this shift. They revise agrarianism by celebrating their urban context and foregrounding matters of difference and inequity. Rather than looking to the past for means of recovering social capital lost or threatened, they embrace both old and new means of building social capital where it has been taken or forcibly dismantled.

As Meleiza Figueroa[40] explains, the Healthy Food Hub 'seeks to pool the resources of its members and the surrounding community to "bring home healthier, tastier, fresher food for less." This is achieved through collective purchasing of wholesale produce, as well as direct food production on rural farms in the historic Black farming community of Pembroke Township, Illinois, located approximately 60 miles south of Chicago.'

The way in which memory animates the Healthy Food Hub's efforts powerfully links land and people, past and present, but in complex ways. Many Healthy Food Hub organizers moved to Chicago as children from agrarian lives in the Mississippi Delta. Their revival of collective buying practices and mutual aid traditions recalls this heritage, mobilizing it to improve the health of their community. Yet, these activists are certainly not celebrating the 'good ole days.' Memories of the land are interwoven with memories of lynchings and oppression. Collective practices are rightly understood as traditions of independence from white—not just corporate—society. They remember 'the Union League, which organized mutual aid networks amongst Black farmers to protect against attacks from white plantation owners'. They remember independent farming colonies like Mound Bayou, a 'utopian experiment founded on notions of self-help and independence from white interference.'[38] Moreover, the move to Chicago is not lamented. Rather, like Williams, Healthy Food Hub organizers stress the linkage of city and country. Processes of dispossession have followed them from Mississippi plantations to urban food deserts in northern cities—and such processes also link them to global histories beyond their own community. Rather than idealizing a particular form or space, these organizers begin the project of decolonization from where they are, drawing on a heritage of collective practices to animate new articulations, more liberated agrarianisms:

> So the sons and daughters of what used to be here in Pembroke—the largest black farming community north of the Mason-Dixon line came here and did not want to know how to farm. They did not want to know anything to do with dealing with the land...[My husband's] father would say, 'What's wrong with you boy? You doing the very thing that we all ran away from. You down there growing food, what's wrong with you?' Constantly, we kept meeting this experience of people being in a lot of pain with the earth. So we all said, 'what's going on here?' The very thing that we need to heal is the thing that all of us have been taught to no longer value. And so we literally buried the pain here...not only did we put the pain back into the earth, we also picked up our power, of our relationship with the earth. We have here strawberries for love and forgiveness. And calendula, for wound healing...fellows came from Uganda and Kenya, and they shared in it...and maybe we can begin to do a global process where we'll release our colonialization and our suffering, and regain our power again.—Healthy Food Hub organizer, 6/21/11[40]

As this organizer articulates, African-American agrarians must remake the category of agrarianism as a precondition of re-engaging with the land. Only through redefinition can injustice be addressed rather than furthered, wounds healed rather than deepened.

A similar project in Milwaukee brings me back to the contrast with which I opened, between canonical agrarian, Wendell Berry, and Growing Power's charismatic leader, Will Allen. Much like the path taken by many Healthy Food Hub organizers, Allen's road to urban food activism runs through a Southern agrarian childhood. His father was a sharecropper in South Carolina, descended from slaves. Thus, Allen's notion of landedness is inextricably linked to the plantation economy of the American South and with racialized dispossession. Yet Allen's memories reinforce both a hunger for social justice

and a strong affective bond with land, plants and animals. When the former basketball player settled in Milwaukee, he realized this brand of agrarianism in the form of a two-acre urban farm, situated in the city's working-class northwest side. Soil health matters just as much to Allen as to Berry, yet the urban farmer cites different reasons, and has employed different methods. 'When you're producing a quarter of a million dollars' worth of food in such a small space, soil fertility is everything,' Elizabeth Royte[41] notes of Allen's operation. Allen uses red wigglers —worms—to churn out rich, copious compost on limited acreage. His ecology is urban, so part of Allen's agrarian connection is the six million pounds of spoiled food he diverts from landfills to feed his compost operation. His agrarianism, like that of Berry or Jackson, also involves banding together with similarly situated farmers. Yet the lines of difference and disadvantage along which this happen differ from those sketched in Berry's Kentucky or Jackson's Kansas. 'Allen was sharing his land with Hmong farmers,' Royte reports, 'with whom he felt some kinship after concluding that white shoppers were spurning their produce at the farmers' market.' In his own 'Good Food Manifesto for America,' Allen serves up an agrarian vision, not of reconnection or paradise returned, but rather of redemptive justice: 'It will be an irony, certainly, but a sweet one, if millions of African-Americans whose grandparents left the farms of the South for the factories of the North, only to see those factories close, should now find fulfillment in learning once again to live close to the soil and to the food it gives to all of us'[42].

Conclusion

Allen's work is a significant re-articulation of agrarianism, but there is nonetheless a striking similarity between his words and those of Wendell Berry. Both begin by citing multigenerational personal agrarian histories, urging us to value ties to land and rebuild them if we have been alienated. Both appeal to universal human experience in describing the transformative possibilities of cultivation, celebrating the potential for literal common ground. That two such differently situated Americans find community and self-expression through this discourse should encourage us critical agrarians. We may be onto a language in which we can have truly democratic, socially transformative conversations. For the heart of agrarian thinking, as political theorist Kimberly K. Smith argues, is the notion of 'common grace,' which reminds us that we must work together to sustain our fragile social and natural worlds[43]. Berry and Allen, Treviño Hart, Rivera, Cortez colonists, Japanese strawberry sharecroppers, and Healthy Food Hub organizers are all engaged in this work. Bringing the weight of their different experiences to bear, they dialogically sharpen and inform a commonly understood goal: shared agrarian prosperity.

In the process, we can change each other's minds. When a recent conflict pitted the Pembroke farmers against The Nature Conservancy for control of their land, canonical Leopoldians might have sided with the conservation organization. Yet many contemporary agrarians sympathize with the farmers. A younger Wendell Berry equated cities with crime and moral downfall, but now he works alongside Will Allen, sharing the podium with him at conferences and celebrating the achievements of Growing Power. The progress we have made in reframing each other's agrarianisms through a critical agrarian conversation is far from complete—but it is decidedly hopeful.

Moving forward, our strength must come from our honesty. If responsible agrarian work creates the social and environmental goods that underlie a just prosperity, do its rewards truly flow back to those with their hands in the dirt? Where have debt loads, discriminatory legislation and redlining impeded such socio-ecological reciprocity? How can we realize an agrarianism in which practices—not paperwork—are truly the basis of material and social community?

The final step, I think, will be to celebrate our agrarian possibilities without recourse to exceptionalism. We can claim value in the relationships we build, without claiming that farmers alone make 'the best citizens.' While acknowledging many real lines of difference, we must stop drawing the false divides of urban/rural, cultivator/worker and local/global that cut us off from our goals just as we stand closest to reaching them. Rather, as Williams, the MST, the Cortez Colony, the Healthy Food Hub and Growing Power encourage, we must extend our webs outward rather than inward, understanding our connection to the work of land tenure reform, education, community development, immigrant advocacy and trade policy. To be an agrarian, then, is not to preserve fixed social–natural ties, but rather to practice a powerfully open and dialogical engagement with the world and one another. Given the troubled histories that have shaped our engagement with the land, such a project will be rife with contradictions, which we must confront squarely as they arise. Yet we must not be afraid of the ever-imperfect state of affairs that awaits us in the dirt. In the words of Donna Haraway[44], 'I think we learn to be worldly from grappling with, rather than generalizing from, the ordinary. I am a creature of the mud, not the sky.'

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Exit of youths and feminization of smallholder livestock production–a field study in India

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Abstract

Studies in India from the early to late 1990s found that rural youths and women played a predominant role in livestock farming. Even though many studies differ in the extent and nature of the contribution of youths and women in livestock farming, all acknowledge their roles and contribution. Livestock farming acts as a source of supplementary income to youths and women and provides increased nutritional security. New economic policies of the1990s have brought changes to the livestock farming community. This paper attempts to understand and describe the role of women and youths in livestock farming. The research methodology employed for the present study is *ex post facto* design, and includes semi-structured open-ended interviews, observation and conversations with key informants. The study has found that a change in the roles of women and the participation of youths in livestock farming has occurred, which could be detrimental to the well-being of rural family farmers.

Key words: smallholder livestock farming, withdrawal of youths, globalization and women

Introduction

In rural India, smallholder livestock farming is one of the important available livelihoods. It is a source of supplementary income and acts as a nutritional and economic buffer during crop failures. Major societal classes in livestock farming are landless, small and marginal farmers. Livestock farming engages 75 million women and 15 million men. Among the rural women, 85% are engaged in livestock activities[1]. They account for 69% of the total labor force engaged in this sector[2], while in crop farming, women account for only 35%[2] of the total labor force. In addition, livestock farming increases women's control over their income and thus promotes gender equality and poverty reduction[3]. Women actively participate in all activities and act as a major source of labor for the livestock sector[4–7]. They spend 77–210 min day^{-1} in livestock farming across the country. In the majority of families, women participate in indoor jobs such as cleaning of sheds, offering feed and water, making dung cakes for fuel, milking, ghee making and also grazing[8–11]. Male involvement is higher than that of women in bringing fodder from the field, chaffing fodder, cleaning of animals, breeding, health care and marketing[7,9]. In addition, past studies have found that the participation of youths in livestock farming as labor force was strong and their participation ranged from 29 to 59% of the labor force in livestock farming across the country[12–14]. In the past two decades, Indian agriculture has seen waves of changes in the context of globalization. During this period, the contribution of agriculture to the national gross domestic product (GDP) has declined from one-third to less than one-fifth[15]. Similarly, the dependence of rural populations on agriculture has been reduced. In 1983, agriculture accounted for 63% of all employment opportunities; in 2005, it was reduced to 56.6%[16] and these facts are further confirmed in the 2011 population census. Over the past two decades, specifically in Tamil Nadu state, the rural population has declined from 66 to 52%. Based on these facts the World Bank 2008 Report on Agriculture has designated India as a 'transforming country'[17]. With this background, this paper attempts to understand the role of women and youths in livestock farming in the context of globalization.

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Methodology

The research methodology employed for the present study was *ex post facto* design. In this study, semi-structured open-ended interviews, observation, interaction with key informants and the published information were utilized. Salem district of Tamil Nadu was selected on account of its high livestock activity in the state. Out of the 20 blocks (administrative divisions) in Salem district, the Sankari block was selected, which has a wide range of livestock activities and which represents the ongoing transformation of the state from an agrarian economy to an industrialized economy by increasing production of transport services for goods, truck body building and textiles. A total of 60 farm families from four revenue villages of Sankari block were selected randomly for the study.

Results and Discussion

Age profile of the farmers

From the 60 farm families, 71 women and 58 men participated in livestock farming-related activities. Among the women, 11.26% were in the younger age group (≤35 years); 33.80% were middle aged (36–45 years), and the remaining 54.92% were in the old-age category (≥46 years). The average age of the women was 47.48 years, as shown in Table 1. In the case of men, 1.72% were in the young category; 32.75% were middle-aged and the remaining 65.51% were in the old-age category. The average age of farm men was 51.31 years. This study confirms that most livestock farmers were in the 'old-age' category, especially men. In addition to the above, participation of women members from households was higher than the male members (1.18:0.96). The results deviated from the past findings, which indicated strong youth participation in the 1990s. However, the findings of this study were similar to other recent studies[18–20]. The results indicate a withdrawal of youths from livestock farming.

Gender and role

Table 2 shows that in the majority of households women were involved in preparation of feed (93%), offering feed and water to animals (92%), cleaning of animals and animal shed (>80%) and grazing (73%) (Fig. 1). In the above activities, the participation of men accounted for 6–14%. In 50–65% of the households, women were the sole source of labor for milking of animals, collection of eggs, breeding and health care management (Figs. 2 and 3). In 27–37% of the households, men were the sole labor source for these activities and in 7–15% of the households, both the genders were involved the above-mentioned activities in the study area. In 45% of the households, men executed the activities of purchasing animals and marketing of livestock and livestock products. In 17% of the households, women executed these activities, and in the remaining households it was a joint activity involving men and women. In comparison with the past studies, the present study found that female participation has increased in breeding, health care management and marketing. The average time women spent in various animal husbandry activities was 4.88 h day^{-1}, whereas the men spend 1.76 h day^{-1} in livestock-related activities. This clearly indicates that there is an increasing workload for women compared to men, resulting in increased feminization in livestock farming. More than 52% of the farm women reported that in the past 10 years their workload in livestock activities has increased. Among them, 70% felt that men have shifted from agriculture to non agriculture activities; 13.5% of the women reported a lack of availability of hired labor for crop husbandry, which forces male labor to spend more time on crop farming, thus resulting in a shift of the workload related to livestock to women. Furthermore, 13.51% reported the aging and death of male counterparts as the reasons for the increased workload of women in livestock farming.

Table 1. Age-wise distribution of farmers engaged in livestock farming.

Age group	Women	Men
Young age (0–35 years)	8 (11.26%)	1 (1.72%)
Middle age (36–45 years)	24 (33.8%)	19 (32.75%)
Old age (above 46 years)	39 (54.92%)	38 (65.51%)
Total	71 (100.00%)	58 (100.00%)

The above findings have occurred largely due to the growth of the industrial sector, such as textiles[21] and transport services. In the study area, the goods transport industry had 1500 trucks in the 1990s and in 2005 it had increased to almost 25,000. Similarly, other supporting industries, namely lorry body building, servicing and auto financing firms, have expanded and developed. In addition to cargo services, the textile sector has developed over the past two decades[21]. The development of the cargo and textile sectors provides lucrative jobs which act as *pull factors* for the farm men and youths, enticing them to move out. This, in turn, results in the shifting of livestock-related activities to the women members of the household who have limited mobility outside the home, due to cultural reasons.

Reform policies in the livestock sector, namely the National Livestock Policy Perspective 1996, the Milk and Milk Products Order 1992, the Multi-State Co-operative Society Act, and state-level livestock sector policies, have encouraged private sector participation in the livestock sector[22]. In addition, the financial support to agriculture and allied sectors from state and central governments (public investment) has been in decline[23,24], resulting in the slow displacement of government and dairy cooperatives from cattle breeding services and milk value chain[25], respectively, and private companies are taking

Table 2. Involvement of farm women and men in various livestock-related activities.

Activity	Women	Men	Both
Bringing fodder from field	48 (80%)	9 (15%)	3 (5%)
Preparation of feed for animals	55 (93.2%)	3 (5.08%)	1 (1.69)
Grazing of animals	44 (73.33%)	4 (6.66%)	12 (20.0%)
Offering feed/water to animals	54 (91.52%)	2 (3.38%)	3 (5.08%)
Cleaning of animal shed	51 (86.44%)	8 (13.55%)	0 (0%)
Cleaning of animals	50 (84.74%)	5 (8.47%)	4 (6.66%)
Milking/collection of eggs	36 (65.45%)	15 (27.27%)	4 (7.27%)
Breeding of animals	30 (50%)	22 (36.66%)	8 (13.33%)
Facilitation of treatment	30 (50%)	21 (35%)	9 (15%)
Purchase of animals	10 (16.66%)	27 (45%)	23 (38.33%)
Marketing of livestock/products	10 (16.66%)	27 (45%)	23 (38.33%)

Figure 1. Women grazing the animals.

Figure 3. Women taking care of health and breeding.

Figure 2. Women bringing the animals to health camp.

their place. This, in turn, results in the withdrawal of low-cost, government-subsidized services and increased cost of production. In addition, poor access to veterinary services, high feed and fodder costs, poor institutional credits, low returns and limited marketing options have been the major constraints to smallholder livestock farmers wanting to move out from livestock farming. Withdrawal of subsidized public sector services and the opening up of market forces act as '*push factors*' for the movement of youths out of small-scale livestock production. The *push* and *pull* factors in the Indian economy have resulted in the poor participation of men, withdrawal of youths and the increased workload of women and the elderly in the livestock sector. In the future, finding successors for running day-to-day livestock operations will likely be challenging. The withdrawal of youths on the production side may hasten the weakening of the smallholder production system, resulting in a severe labor shortage. In the long run, the exit of smallholders from livestock farming and the emerging demands from ongoing urbanization of the country[17] may pave the way for industrialization of livestock farming. In Brazil, new economic policies acted as 'push factors' and have resulted in the closure of small-scale farms, which paved the way for establishment of large-scale livestock farms[26]. Indian smallholder livestock production is also being presented with a similar situation, with 70% of the rural population

forced indirectly to move from their livestock-based livelihoods[3].

In addition, Indian smallholder livestock production exists in a symbiotic relationship with crop husbandry. The livestock provides manure and draft power to the crop husbandry, and crop husbandry supports livestock with crop residues as feeding materials. This smallholder livestock production is more environmentally friendly and has low environmental costs in comparison with larger farms[27]. With poor participation of the young, the elderly labor force in smallholder livestock production may cause the relation between crop and livestock farming to be weakened. The disturbances in crop–livestock interaction may have an impact on the productivity of both crop and livestock. If the weakening smallholder livestock production system is replaced with large-scale farms, there may be higher chances of environmental disturbances[26]. Thus, these changes may threaten the livestock-based livelihood of rural populations and their environment.

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Exploring linkages between Consumer Food Co-operatives and Domestic Fair Trade in the United States

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Abstract

Consumer Food Co-operatives (co-ops) have provided consumers an alternative to corporate supermarkets and big-box stores since the 1960s. Producers seeking broader marketing opportunities often turn to co-ops. This study examines how, within alternative food networks (AFNs), co-ops play a role in the emergence of the Domestic Fair Trade (DFT) movement in the USA. The DFT movement is based on the idea that family farms and small- to mid-sized farms in the global north are facing many of the same pressures as producers in the global south. The Domestic Fair Trade Association (DFTA) in the USA is the umbrella organization for a variety of stakeholders. The DFTA seeks to 'support family-scale farming, to reinforce farmer-led initiatives such as farmer co-operatives, and to bring these groups together with mission-based traders, retailers and concerned consumers to contribute to the movement for sustainable agriculture in North America'[1]. This study assessed five co-ops (through interviews and document analysis) to determine their experiences with integrating DFT into their business practices. The research reveals that DFT concepts are important to co-operative decision-makers, but they are faced with challenges when it comes to actually integrating DFT into their business model. Insight into stakeholder perceptions and professional-level DFT activities, indicates that co-ops will be a key factor in determining whether the DFT movement will succeed in the USA.

Key words: alternative food networks (AFNs), Consumer Food Co-operatives, Domestic Fair Trade, global food system, United States

Introduction

Increasing concerns about our global food system have led to the development of a variety of alternative food networks (AFNs) or values-based food networks[2–8]. AFNs are 'new and rapidly mainstreaming spaces in the food economy defined by, among other things, the explosion of organic, Fair Trade, and local, quality and premium specialty foods'[9]. The degree to which these alternatives interact, complement or compete with one another is not well understood. This study illuminates the interactions between two stakeholders in AFNs: Consumer food co-operatives (hereafter called co-ops) and Fair Trade (specifically Domestic Fair Trade or DFT).

Co-ops in the USA have been viewed as a political and economic alternative to conventional supermarkets since the 1960s[10]. The very nature of consumer food co-ops lends itself to being a complementary avenue for alternative movements. Food co-ops operate according to a common set of seven principles that are agreed upon by the international co-operative community: voluntary and open membership, democratic control, member economic participation, autonomy and independence, education, training and information, co-operation among co-operatives and concern for community[11–13]. There are currently 394 food co-ops in the USA (Fig. 1). Many of these stores focus primarily on natural foods, but some offer a full line of grocery items[14].

The Fair Trade movement has brought issues of social justice to the food production conversation and now factors such as social equality, fair trading relationships, labor rights, etc. [15] have a place along with environmental and human health concerns. Fair Trade products are produced and traded in accordance with these principles —wherever possible verified by credible, independent assurance systems. Indeed, the World Fair Trade Organization, a global network of Fair Trade groups

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Figure 1. Location of food co-ops in the USA.

notes that: 'Fair Trade is a trading partnership, based on dialog, transparency and respect, that seek greater equity in international trade. It contributes to sustainable development by offering better trading conditions to, and securing the rights of, marginalized producers and workers—especially in the South' [16]. Further noted by the Fairtrade Foundation in the UK: 'Fairtrade is a strategy for poverty alleviation and sustainable development. Its purpose is to create opportunities for producers and workers who have been economically disadvantaged or marginalized by the conventional trading system'[17].

Although some consider social justice problems to be an issue exclusive to marginalized economies, recent campaigns have exposed injustices and devastating impacts of globalization on rural communities in the USA[18]. There has been a growing movement within the USA (and other countries within the global north[1]) focused on situating the principles of international Fair Trade within a domestic context. In 2007, the Domestic Fair Trade Association (DFTA) was formed to find solutions to the issues facing farms in the USA. Their main goals are 'to support family-scale farming, to reinforce farmer-led initiatives such as farmer co-operatives, and to bring these groups together with mission-based traders, retailers and concerned consumers to contribute to the movement for sustainable agriculture in North America'[1].

Movements within AFNs

AFNs generally act in opposition to the global, industrial and environmentally degrading conventional food system[20]. They seek to redistribute value through food networks in the opposite direction to the bulk commodity system and to re-instill trust between the producer and consumer as articulated by new forms of governance and political association[21]. Typical AFNs in the USA come in the form of farmers' markets, community-supported agriculture, organics, Fair Trade and local food campaigns[3,22].

[1] Use of the terms 'global north' and 'global south' provide a broader and more open definition of global difference in 'an attempt to correct the use of other economically based terms, such as First World and Third World and developed world and developing world, as well as core and periphery'[19].

'Buy local' food campaigns have been prominent in recent years and it is now common to see a local label on produce in retail food stores. Nutritional, economic and environmental benefits are associated with buying local foods, but there is ongoing debate as to how local scale impacts natural resource use and crop seasonality, if local farmers receive sufficient benefits, and whether local foods are accessible to lower income consumers[9,20,23,24], pointing out that the ontology of local is taken as a given, not as a category that is socially constructed. Although it is easy to support the local food movement as inherently good, when assessing an AFN, there is still a need for a mechanism to ensure the social and ecological benefits of these alternative food systems[25].

Jarosz[26] explores AFNs in particular locations in order to understand relationships of trust and cooperation. Instead of focusing on the 'local,' she looks at regional food networks embedded in rural landscapes that are nested within globalized agro-industrial commodity and capital flows. When it comes to the pursuit of progressive local-scale development, there is a need to emphasize the formation and mobilization of a consciousness of justice and a multi-scale understanding of place that can then be linked with other local-scale ventures and/or larger scale actors[27].

Addressing initiatives, such as community-supported agriculture, farmers' markets, local food campaigns and certain organic communities, Allen[28] points out the gap between the intent and the outcome in these networks. Indeed, social justice (or democracy or sustainability), not localization or globalization, should be the focus for changing the structure of the current food system[25]. Organic initiatives are an example where social justice needs to be addressed and a convergence of movements may bring about equitable change in the food system. As organic sales have grown, the distance between producer and consumer has increased, causing some organic agriculture to look quite similar to conventional production[29]. One indication of this conventionalization of organic agriculture is the employment of migrant wage labor and the abandonment of many sustainable agronomic practices[30].

Integrity of any alternative agricultural system should cultivate competition among producers for the highest possible standards instead of one that pushes practices toward the lowest common denominator[31]. Raynolds[29] discusses a convergence of the Fair Trade and organic movements in order to re-assert the organic movement's founding concepts, and DuPuis[32] introduces Fair Trade markets as potential alternatives for smaller organic farmers to gain access to mainstream buyers. Overall, there needs to be further empirical research and analysis in the places and space of production and there is a need for research to connect Fair Trade production and markets at all scales (e.g., global, national, regional, local and household)[33].

International Fair Trade is intended to provide an alternative to the conventional market where the masses are excluded from active participation, the degradation of the environment is tolerated, and where labor becomes another commodity through the objectification of human relationships[34]. Fair Trade exists because international commodity chains lack transparency and this creates distrust in global food systems[35]. Consumers in the global north perceive unfairness in the structure of conventional food trade and consumer research has focused on the socio-psychological aspects that motivate purchases[36]. Indeed, some researches go so far as to state that a Fair Trade purchase 'is essentially a bundle of a base product and a donation to the supplier'[37]. Fair Trade is bolstered by the fact that unfair economic relationships are the direct result of trade priorities and criteria set by the global north, but impacting producers in the global south[38]. Thus 'Fair Trade seeks to transform North/South relations by fostering ethical consumption, producer empowerment and certified commodity sales'[39].

Some voice concern about adopting an international term for a domestic movement[40], but others would argue that there is potential for DFT to develop links with other values-based consumer campaigns and to expand consumers' conceptualization of Fair Trade[1]. These links have the potential to broaden the understanding and applicability of the Fair Trade principles that are focused on restructuring markets at home[41,42].

DFT can help resolve some of these issues and create more of a civic coordination among participants in the food network[38]. Many of these local food systems have developed in uneven patterns and in idiosyncratic ways and could benefit from a set of standards that might bring a more systematic and cohesive approach to alternative food systems[41]. Alternative systems in the USA could benefit from local autonomy through DFT. This local autonomy as described by Bellows and Hamm[43] is not an isolated process of self-sufficiency, but rather the ability to negotiate power and needs from a local starting point across geographic space and across barriers of social constructs.

A co-operative model of food and agriculture has developed as a social and economic movement, through which consumers have personal relationships with co-operative members who, in turn, have direct links to southern partners through International Fair Trade[44]. Co-ops typically have a place in the International Fair Trade market; so introducing and integrating DFT could have the potential to provide more support for the Fair Trade movement and bring more consumer and producer education to the workings of Fair Trade in the north and the south. 'By utilizing "Fair Trade"' as a universal term to describe a broader range of alternative market initiatives, consumers might be better educated to make the links between the processes driving small farmers in both north and south to economic collapse and off the land'[42].

Table 1. Structure of sampled food co-ops.

Co-op location	Year EST.	Members/owners	Staff	2010 Annual sales	Retail stores	Board	Management (mgmt) structure
MA 1	1981	~2200	70	US$7.9 million	1	9	General manager and mgmt team
MA 2	1977	1990	74	US$7.8 million	2	11	Three-person mgmt team
MN 1	1972	950 households	25	Unknown	1	6	General manager and mgmt team
MN 2	1972	~7500	185	US$21.3 million	1	9	General manager and mgmt team
NY	1976	6778	75	US$13.5 million	1	8	Mgmt team: 11 managers

In a study conducted by Howard and Allen[45], consumer willingness to pay for DFT points to co-operative food stores and buying clubs as promising outlets for establishing DFT. Their study suggests efforts to establish DFT should begin by targeting retail outlets frequented by these types of alternative consumers, namely consumer food co-operatives. Incorporation of DFT into co-ops can set the stage for empowerment where contractual mechanisms exist between consumers and producers on the construction of collective choices[46]. Through this type of mechanism and co-operation, DFT networks can link regional consumers and producers.

Because the DFT movement is so young, there is very little information on how it actually intersects with different groups of stakeholders within AFNs and whether it is a movement capable of creating ethical linkages across social and physical space. Indeed, interaction between DFT and co-ops seems particularly logical because of their common principles, and the fact that both are propelled by stakeholders with similar goals for equity in food production and consumption. In light of all of the emerging AFN players, the question arises: do co-ops and DFT goals overlap and work in unison to promote social and political change throughout alternative food systems?

Methods

This research explores the experiences and practices of co-ops to understand how DFT influences the AFN movement in the USA. This research sought to identify reasons for co-ops' involvement with the DFTA and the methods of integrating DFT principles into their organizational practices. Further, the research illuminates how the institutional goals of DFT are practiced within day-to-day operations of co-ops in the USA. In order to investigate these relationships, we answer two specific questions: first, how do co-op managers describe their co-op's experiences with the integration of DFT? Secondly, what are the key focus points for DFT at the organizational level and how do those compare with what food co-operatives are actually implementing? Through the exploration and analysis of these questions, this study illuminates the extent to which the DFT movement is present within co-ops.

The National Co-operative Grocer's Association (NCGA) acts to unify business services for natural food co-ops in the USA. They 'represent 128 food co-ops operating 165 stores in 35 states with combined annual sales of over US$1.4 billion and over 1.3 million consumer–owners'[47]. The NCGA is an organizational member of the DFTA, which means that all co-ops are loosely affiliated with this organization. For this study, however, we specifically focus on co-ops that are individual members of the DFTA, which is beyond the umbrella affiliation that co-ops have through the NCGA umbrella.

Co-ops with specific interest in the DFT movement were selected for participation in this study in order to best understand the fledgling nature of these interrelationships within the broader context AFNs in the USA. In total, there are six consumer food co-ops that are independent members of the DFTA, and five agreed to participate in this research. Thus, a manager at five co-ops participated in an interview and these texts were transcribed. Qualitative analysis (constant comparative method) was conducted on the interview transcript data[48–50]. The participating co-ops are located across the USA: Massachusetts (2), New York (1) and Minnesota (2). Although each of these co-ops has a similar structure and organization, some characteristics vary, which makes each of their experiences with the integration of DFTA into their business unique (Table 1).

This study also included a document analysis of key documents from four years of DFTA annual meetings (2007–2010). Specifically, this textural analysis included: meeting minutes, program outlines, meeting schedules, topics of presentations and discussion topics. Content analysis was used to determine the key focus points of DFT at the organizational level[51]. Finally, the qualitative cross-case comparison analysis was used to combine findings from the interview data and document data[48,50]. This provides an assessment of how co-op experiences parallel or diverge from DFT organizational goals.

Findings

Based on the results from the interviews with co-op managers, two common themes emerged: (1) DFT concepts are inherent within co-op activities, and (2) many challenges exist for incorporating DFT into co-op business practices (Table 2).

Table 2. DFT: common themes among co-op managers.

Theme 1: DFT inherent in co-ops	
Finding 1	DFT activities are inactive and considered low priority by co-op managers
Finding 2	Education of consumers and helping small farms grow are important accomplishments for co-ops (seen as promotion of DFT)
Finding 3	Co-ops create opportunities for open communication, partnerships and fair relationships with other stakeholders in AFNs (seen as DFT)
Finding 4	Currently, interaction with the DFTA depends mostly on the individual co-ops seeking support
Theme 2: Challenges for incorporating DFT into co-op business practices	
Finding 5	There is no DFT certification or labeling; no tracking mechanism to assess percentage of products that are DFT
Finding 6	DFT is often interchanged with other AFN terms, also seen as competing with other AFNs
Finding 7	DFT faces a perception that farmers/producers/laborers in North America do not face similar injustices as those in Global South nations
Theme 3: Co-op consumer knowledge of DFT	
Finding 8	Co-op managers say that stakeholders within their food networks possess little awareness of the co-op's commitment to DFT
Finding 9	Managers believe Fair Trade is important to a majority of their customers, but feel they are not willing to pay a higher price for it

DFT inherent in co-op

The consensus among all co-op managers was that DFT was an extension of their existing values and beliefs. Yet, co-ops reported placing a low priority on the specific DFT work. In fact, several noted inactivity (*Finding 1*) related to DFT. Indeed, becoming paying members of the DFTA and supporting the organization are the two primary activities that co-ops noted when asked to describe their DFT activities. They have time for little else, according to co-op manager 4, DFT is 'on the back burner, so to speak'. Multiple times during the interviews, the managers noted that becoming a member of the DFTA takes a considerable amount of time and money. Busy co-op managers say they simply do not have additional time to specifically address DFT issues 'separate' from other topics of relevance to their members and consumers. They feel that their co-ops already integrate Fair Trade principles into their business practices, so devoting additional time and resources to the DFTA was not necessary. 'Food co-ops can do very well by using FT principles and DFT principles... with or without the [DFTA] organization' (co-op manager 3).

Co-op managers say they promote DFT through educating consumers (*Finding 2*) in the form of store demos, articles in monthly newsletters and in-store bulletin boards. Through this education, other stakeholders within the food chain are also becoming more aware of Fair Trade issues. Another aspect of the DFT movement is increased communication and partnerships (*Finding 3*) among AFNs. Co-op managers mentioned that the issues of DFT were sometimes a topic for discussion with other co-operatives and with local farmers. 'Fair trade is a topic that comes up, but I wouldn't say it is a reason for the communication...more that there's been more communication about that because of enhanced communication between co-ops overall' (co-op manager 1).

On the other hand, co-op manager 3 said that the concept of DFT opened up communication, which had a positive impact: better business opportunities for them and their producers (*Finding 4*). 'We've literally been able to write fair trade agreements with producers and it's helped them grow their business and it's helped us get the right product. And we're doing that even when those farms aren't certified [organic] because it just makes sense. I mean they're principles that make sense both financially and ethically'. In this case, the co-op is using Fair Trade principles to build collaboration with local farmers rather than using 'certified organic' as a criteria for identifying farmers.

Challenges for incorporating DFT in co-ops

Co-op managers said that despite the various opportunities for supporting and getting involved in the DFTA, they are often unable to participate or promote DFT in significant ways. The organization solicits participation in committees, but the co-ops are mostly inactive, as members and staff do not have time to build interactions.

In their interviews, co-op managers were asked to estimate the percentage of items in their store that they considered DFT products. Three of the interviewees indicated that most of the domestic products they carry embody the principles of DFT but they are not labeled as such. Indeed, there is currently no certification or labeling (*Finding 5*) for DFT, so no tracking mechanism is in place. Unless an organization is a member of the DFTA and the co-op investigates a producer's DFTA membership, they cannot technically consider a product DFT. Few co-ops spend time conducting this verification.

While the lack of labeling is an issue with DFT, the introduction of another label within the AFN marketplace is a significant concern. Consumers must read and understand a lot of information at a typical co-op and it

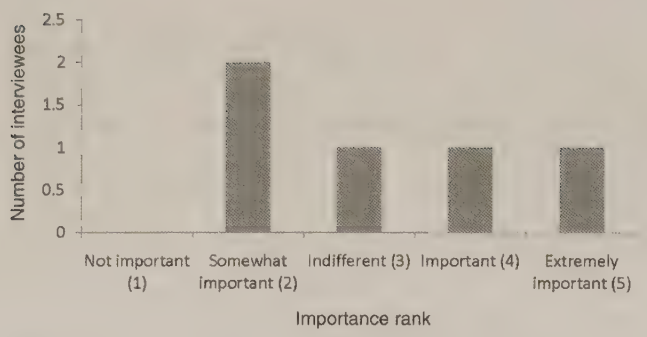

Figure 2. Co-op manager ranking: 'How important is fair trade to your customer?'.

may be too much to introduce one more label or term. There is already oversaturation of labeling, criteria and adjectives in the grocery marketplace; adding another label would add to the confusion (co-op manager 4, 2010).

Managers often view their relationships within local food networks as an embodiment of DFT. Co-op manager 3 went on to explain that they sell local foods, which they define as items grown within 151 miles of the co-op:

> We call it 'Area 151' and the food products that we buy in that area are 17% of our total food purchases in a year. So, while we strive to have open and fair relationships with all of those organizations (all those businesses) we cannot say that they are fair trade.

Although DFT overlaps with local food, it may also compete with international Fair Trade (*Finding 6*), which is a fairly recognizable label that extends beyond co-ops and natural food stores into the mainstream marketplace (co-op manager 4). There is a lot attention going to local food initiatives right now and international FT is a largely accepted and recognized label, therefore trying to incorporate yet another movement or label is too much for consumers (co-op manager 2, 2010).

Some Americans lack an understanding of the need for Fair Trade in the US context (*Finding 7*). Two co-op managers described this challenge:

> I think as North Americans, it's hard for people to conceive that there should be a justification for fair trade. They may look at that making the leap from looking at Central American or a South African country that have poor people and what fair trade can do for them (they can grasp that or think of that), but I think it's a harder leap when you're talking about that being in our same country. (co-op manager 2)
>
> I think a lot of people in this country just assume that there's no need for DFT rules and regulations because after all, this is the USA and we don't do terrible things like they do in 'third world countries'. So, it's more than education, it's breaking perceptions. That will be tough...and to do that without admonishing will be a difficult task'. (co-op manager 5, 2010)

These co-op managers explained that there is a strong network for international Fair Trade issue, but a lack of consumer understanding when it comes to our domestic food system. For example, some consumers assume that organic certification includes social/economic concepts to help family farms.

Managers believe that their customers view Fair Trade as 'somewhat important' (Fig. 2). However, all interviewees said their ranking was an average and that there are definitely 'core customers' who care very deeply about the issue. On the other hand, some customers probably do not think about DFT at all. Indeed, managers say that most shoppers do not care about DFT, and would not pay more for a product just because it claimed to be DFT (*Findings 8* and 9). Manager 3 stated pointedly, '...there's certainly a core group that would place it higher, but I think right now, in this climate, they could take it or leave it'.

The findings from these interviews lead to a better understanding of each co-op's experience with integrating DFT into their business. Next, the analysis explores the extent to which DFT goals at the organizational level are manifest in co-ops.

DFTA Focus and Co-ops

The DFTA is a non-governmental organization that plays a key role in the Fair Trade movement[40] as it seeks to 'promote and protect the integrity of DFT principles through education, marketing, advocacy and endorsement'[52]. The DFTA upholds these diverse and multi-faceted principles:

> ... family-scale farming, capacity building for producers and workers, democratic & participatory ownership & control, rights of labor, equality & opportunity, direct trade, fair & stable pricing, shared risk & affordable credit, long-term trade relationships, sustainable agriculture, appropriate technology, indigenous peoples' rights, transparency and accountability, education and advocacy, responsible certification and marketing and animal welfare[52].

The DFTA clearly recognizes the important position that co-ops play in building AFNs. In fact, the DFTA adopted a resolution supporting the '2012: International Year of Co-operatives,' which states that they

> ... recognize and promote the vital role of co-ops in the food system and in the economic and social well-being of communities from the global level to the local; encourage stakeholders in the food system to consider how the values and principles of the co-operative movement relate to those of Fair Trade and can contribute to health, justice and sustainability[53].

Indeed, co-ops fit into the DFTA membership structure as a retailer. The DFTA has four different membership categories: (1) farmer organization, (2) farmworkers' organization, (3) retailer/processor/marketer/manufacturer and (4) non-governmental organization[54]. All members pay annual dues based on their sales or operating budget,

Interview findings	1	2	3	4	5	6	7	8	9	Interview findings	1	2	3	4	5	6	7	8	9
DFTA key focus points										***DFTA key focus points***									
Adding members										Include all stakeholders in discussion			X					X	
Address DFT criticisms						X				Incorporate living wage model									
At-will employment										Increase buyer and retailer members									
Become clearinghouse for Info about food										Increase DFT products					X			X	X
Building a broad movement			X							Increase family-scale farms		X							
Chapters and define member tiers	X				X					Increase farmworkers as owners		X							
Concrete message among members								X		Increase presence in public eye							X	X	
Criteria creation: evaluate claims					X					Measure progress through research									
Declare food co-ops as DFT zones	X							X		Member evaluation process	X			X					
DFTA at FTF Conference?										More diversity and indigenous									
DFTA defined										More organic production									
DFTA scope										More workers becoming farmers									
Educate workers		X								Policy role									
Foster linkages among groups		X								Public education		X					X	X	
Further producer control		X								Social justice in organic									
Health care in food systems										Stakeholder unification			X						
How labels / certification fit					X			X	X	Unite certifiers					X				
Identify more resources	X																		

Figure 3. Comparing overlap between co-ops and DFTA.

and these vary from under US$100 to several tens of thousands of dollars. Members are expected to formally endorse the principles of DFT and constantly make progress toward the goal of full compliance[55].

In addition to its informative website, the DFTA holds an annual meeting where members participate in the decision-making process for the association and discuss issues and concerns. Document content analysis was used to create a list of key topics from each DFTA annual meeting, held in 2007–2010 and Fig. 3 provides a comparison of the interview findings and meeting focus point findings. This illuminates how the experiences conveyed by the co-op managers relate to what occurs at the professional level. This cross-case comparison further explores the findings that emerged from the interview portion of this study.

The nine interview findings are listed across the top of the matrix and the DFTA key focus points are listed in alphabetical order in the left-hand column. Interview findings that are linked to one of the focus points are shown by an X in the corresponding box. The result of this comparison is a visual representation of how the co-op findings merge or overlap with the professional-level goals of the group. Consequently, we are able to see which issues both the co-op managers and the DFTA find important.

The results from this comparison indicate that more key points are applicable to *Findings 2* and *8* than to the other findings. Thus, the co-ops' emphasis on education of consumers fits well with the goals of the DFTA. Further, the fact that co-ops work to help small-scale farmers is in line with DFT goals. Finally, increasing awareness of DFT is a point where the co-ops and the professional organization are united. Interview *Findings 1* and *5* both related to four of the key points, thus DFT labeling is of interest to both the organization and the co-ops, but at the same time the co-ops lack time for promoting DFT issues. The remaining interview findings related to three or fewer

of the key focus points, which indicates that co-ops do not intersect with a large number of DFTA goals.

Recommendations

These findings provide insight into co-ops' experiences and how DFTA goals have been realized in co-ops over the past 5 years. Although several key goals do overlap between these two stakeholder groups, there is much room for increased collaboration. At this point, the overlap between co-ops and DFT exists at the conceptual level, as both share a common vision for a more equitable agricultural system. Unfortunately for the DFT movement, co-ops tend to promote these common goals without recognizing them as DFT. If the DFTA is to succeed in linking with co-ops to educate their consumers, several changes must occur. The following discussion is centered on key recommendations for the future of the DFT movement within food co-ops.

Membership

Because membership is a fairly lengthy, expensive and time-consuming process, many co-ops do not currently see the need to join this professional organization. Certainly, DFT principles can be carried out by co-ops without them going through the paperwork and expense of individual membership in the DFTA. However, the fact is that co-ops do not recognize or advertise their actions as DFT. If the DFTA seeks to be the unifying organization in the movement, it must advertise the benefits of membership and provide incentives for expanding their member base. To succeed, the DFTA must provide their members with a clearer picture of what DFT is and what the future holds for the movement. This organization must create a network of members who spread the word and motivate others to become involved in the growing movement. Co-ops are the ideal venue for education about DFT issues, as this consumer base is already informed about food issues and considers information a necessary component of food shopping. Given that co-ops are places to promote DFT, it is surprising that very few co-ops are actually involved with the movement's pivotal organization. Increasing co-op membership would be a valuable undertaking for the DFTA.

Co-ops as DFT zones

The idea that food co-ops should be declared 'DFTA zones' initially came from the 2009 DFTA annual meeting. Clearly co-ops have a unique position in the Fair Trade marketplace for a number of reasons. Co-ops have more personal relationships with various stakeholders in the food network than other retail spaces might. They integrate the social and political aspects of food consumption into their business model. They have access to other AFNs in the country due to the strong co-op network. Finally, co-ops have an educated 'foodie' consumer base that could take the DFT movement to the next level of acceptance among the general public. Our findings indicate that the co-ops are beginning to realize that DFT has the potential to build new channels of communication among multiple stakeholders throughout the AFN. Therefore, if the DFTA promotes co-ops as DFT zones, they may be able to address their goal of uniting stakeholders. However, key barriers remain, especially related to geographic variations across the food landscape.

Local/regional Fair Trade

This is an issue of scale. Our findings suggest that the national DFTA organization may be unable to accomplish the real-world goals of linking farmers to consumers in the USA. Indeed, the popularity and success of the local food movement indicates that alternative networks are focusing on local-scale relationships rather than national-level organizations. Creating regional chapters was discussed at the 2009 DFTA annual meeting. This may also allow DFT goals to be promoted by locavores, who also seek to avoid large-scale, industrial food distribution. Grassroots local food initiatives would see little value in a national organization of DFTA, but might be willing to promote the concept of local Fair Trade (as an off-shoot of Domestic Fair Trade).

Further complicating the issue of scale is how the organic agricultural movement has evolved. DFT provides an opportunity to define a set of structures that could be used to help consumers understand how their food is produced, which would build an educated consumer base. This could help farmers earn a fair wage for their products. DFT could be developed into a label that would provide consumers with confidence that their purchase is helping a family farmer remain viable. As it now stands, the local food movement is coming to the forefront of American society: consumers want to know their farmer. If we each go to a growers' farmers market, we can meet the people whose hard work created our food. However, this lacks viability at a larger scale, as distant populations are unlikely to meet their farmers, even if she/he is a smaller scale 'family farm'.

This research suggests that promoting DFT may be an effective way to educate and involve locavores in the broader Fair Trade movement. However, to do this effectively, more DFT products must be labeled (and this implies a certification to verify the label). Regional chapters of the DFTA could carry out the necessary regional evaluations and strive to determine criteria for compliance with DFT principles at this geographic scale: local/regional Fair Trade.

While overarching DFT standards could be used to unify the movement and increase awareness among stakeholders participating in various links of the food chain, regional implementation would maintain local richness in these AFNs. Given the controversies and

dilemmas of industrial organic and the fact that certified organic only verifies production methods/materials, DFT can fill the need of providing a valid, social certification for small-scale independent family farms.

Conclusion

Findings from interviews and document analysis support the idea that DFT is a 'movement of movements'. Although the term may not always be used, Fair Trade principles are being incorporated into co-ops through their relationships with local and regional producers. Analysis of the DFTA meetings indicates that their key focus points involve integrating social justice into organics, becoming a broader movement, and working to foster linkages among different food stakeholder groups. Co-ops provide an ideal meeting place for these many AFN players and DFTA must build stronger working relationships with co-ops if they are to reach their common goal of eliminating inequalities in the US agricultural system.

Ultimately, this study points to the need for broader collaboration among AFN stakeholders, specifically co-ops and Fair Trade within the US domestic setting. In order to succeed, the DFT movement must educate consumers and producers about the need for a socially equitable system of food production and sales in the global north. DFT, if it is to evolve successfully, could include social concerns to balance the production-only criteria of certified organic production. A DFT label could ensure a set of social standards that certified organic does not address. Certified organic is a production standard in a codified system of 'allowable' substances in the field. Indeed, if stakeholders can be convinced of the efficacy of Fair Trade as a unifying principle for AFNs, it could provide verification of the social sustainability that industrial organic does not provide.

Whether DFT objectives will become a broader movement for social and political change throughout conventional and alternative food systems is yet to be determined. The movement is new and there are still many barriers to be overcome. Insights and findings from this study, however, indicate that there is great potential to unify numerous stakeholders. Specifically, linkages between locavores and organic farming could be realized through DFT principles and articulated by co-ops.

In light of the various emerging stakeholders in AFNs, both co-ops and DFT could promote a broader movement for social and political change throughout conventional and alternative food systems. With the help of concerned co-op consumers, the DFT movement has the potential to build an equitable alternative food system within the US domestic context that supersedes social divides and physical space. If it is successful, co-ops and DFT could empower farmers and consumers to create meaningful, fair relationships that succeed outside the globalizing food economy.

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Essential oil of *Ocotea odorifera*: An alternative against *Sitophilus zeamais*

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Abstract

Nowadays, the maize weevil *Sitophilus zeamais*—Motsch 1855 is the most relevant pest found during storage of maize grains. Aiming at protecting the agricultural crops, high amounts of synthetic pesticides are used around the world. In this sense, this work aimed at evaluating the insecticidal and repellent effect of essential oil of *Ocotea odorifera* (Vellozo) Rohwer (Lauraceae) (*O. odorifera* (sassafras)) leaves against the maize weevil in maize grains. The essential oil's chemical composition showed that sassafras contains camphor (43%) and safrole (42%) as major compounds. Our results show that sassafras oil was insecticidal and repellent to maize weevil. About 100% mortality was achieved using a concentration of 0.32 $\mu l\,cm^{-2}$, after 24 h of exposure. The LD_{50} value was 14.1 µl or 0.09 $\mu l\,cm^{-2}$ and the study of the effect on insect mortality at the lethal doses (LD_{50}) showed that after 72 h mortality was 100%. The values of the preference index varied from −0.39 (0.065 $\mu l\,cm^{-2}$) to −0.63 (0.659 $\mu l\,cm^{-2}$), demonstrating that the plant oil presents repellent activity. The repellency bioassay simulating small bins showed the repellent effect level from 0.64 (0.36 $\mu l\,cm^{-3}$) to 0.94 (2.9 $\mu l\,cm^{-3}$). The essential oil of sassafras presented insecticidal and repellency against maize weevil. Although from an economical point of view synthetic chemicals are still more frequently used as repellents, natural products (essential oils) have the potential to provide efficient and safer repellents for humans and the environment.

Key words: essential oil, repellency activity, insecticidal activity, contact toxicity, *Zea mays*

Introduction

Pests (especially weeds, pathogens and insects) are the greatest challenge to agricultural crops in the world, drastically reducing production, in the range of 25–50%[1,2]. Among the most important pests, weeds alone are responsible for a reduction in crop yields of almost 34%[2]. With the objective of protecting the agricultural crops, high amounts of synthetic pesticides are used around the world. Nowadays, the maize weevil is the most relevant pest found during storage of maize grains.

Aromatic plants and their essential oils have been used since antiquity in flavor and fragrances, as condiment or spice, in medicines, as antimicrobial/insecticidal agents, and to repel insect or protect stored products[3,4]. These oils represent effective alternatives to synthetic pesticides without producing adverse effects on the environment[5,6]. The essential oils of plants have been broadly studied for pest-control, including toxic and repellent effects[7,8], antifeedant, ovicidal and other properties[9,10].

Many plant secondary metabolites such as monoterpenoids have insecticidal activity against stored product pests[11,12]. Hideyuki and Mitsuo[13] noted that the mixture of monoterpenoids could have a synergistic effect on the inhibition of acetylcholinesterase. These authors observed that a limonene, linalool and lynalyl acetate mixture showed a synergistic effect and was more inhibitory than bergamot oil or only the application of monoterpenoids.

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The sassafras tree, a species of the Atlantic Forest ecosystem of South America, is of high commercial value, especially because of its wood quality. Leaves contain oils such as safrole, kaempferol, quercetin and other compounds that may have insecticidal activity, along with other uses. Moreover, sassafras is a phytochemical known by the presence of flavonoids such as kaempferol and quercetin, steroids, sesquiterpenes and essential oils, a component of which is safrole[14].

The leaf essential oils of ten species of *Ocotea* (Lauraceae) from Monteverde, Costa Rica (*O. floribunda*, *O. holdridgeana*, *O. meziana*, *O. sinuata*, *O. tonduzii*, *O. valeriana*, *O. veraguensis*, *O. whitei* and two undescribed species—*Ocotea* new species 'los llanos' and *Ocotea* new species 'small leaf') have been obtained by hydrodistillation and analyzed by gas chromatography coupled to a mass spectrophotometer (GC–MS), and the more common constituents were α-pinene, β-pinene, β-caryophyllene and germacrene-D[15].

Pinto Junior et al.[16], evaluated the essential oils of sassafras and *Eucalyptus viminalis* (eucalyptus) on the control of larvae and adults of lesser mealworm (*Alphitobius diaperinus*), comparing their insecticide potential. They concluded that the essential oils of sassafras and eucalyptus can be used to control lesser mealworm as a new integrated strategy for the management of this pest.[16] This study led us to consider and test these oils on the maize weevil.

Moreover, there are no reports in the current literature analyzing the effect of oil of sassafras against the maize weevil. In this context, the aim of this study was to evaluate the bioactivity and repellent effect of essential oil of sassafras against *Sitophilus zeamais* in maize grains.

Materials and Methods

Plant materials

Leaves of sassafras were collected in summer (March) in Marcelino Ramos (RS, south of Brazil). The identity of the plants was confirmed by the Balduino Rambo Herbarium of the Universidade Regional Integrada in Erechim, south of Brazil (BRH: 11.507).

Procedure for isolation and characterization of the essential oils

The plant material was dried naturally on laboratory benches at room temperature (30°C) for 5 days until crisp. The dried material was stored at room temperature and then hydro distilled to extract the essential oil using a Clevenger-type apparatus for 4 h. The extraction conditions were established as 100 g of air-dried sample and 1:30 plant material/water volume ratio. Anhydrous sodium sulfate was used to remove the water after extraction. The extracted oil was stored in refrigerator at 4°C[8].

The chromatographic analyses of the essential oils were performed using a Shimadzu—QP 5050A series gas chromatograph (GC-MS), using a DB-5 fused silica capillary column (30 m × 0.25 mm internal diameter × 0.25 μm film thickness). The temperature program used for the analysis was: initial temperature at 60°C, held for 3 min, and ramped at 3°C min^{-1} to 180°C, then 20°C min^{-1} to 300°C. Helium was used as a carrier gas at a flow rate of 1 ml min^{-1}. The detector temperature was set to 300°C, and the injector temperature 240°C with injection port (split 1:20). The oil compounds were identified by comparison of mass spectra of each peak with those of authentic samples in a mass spectrum library (The Wiley Registry of Mass Spectral Data, 7th ed.).

Insects

S. zeamais was cultured in a controlled temperature (25 ± 1°C) and at 70–75% of relative air humidity (rh) in darkness. The food medium used was whole maize grains[8]. The adults used in the experiment were 2–3 weeks post-emergence.

Contact toxicity on filter paper

The contact effect of essential sassafras oils against maize weevil was evaluated on filter paper discs (Whatman No. 1) (14 cm diameter, surface 153.9 cm^2), treated with different dosages of oil. The filter papers were placed in glass Petri dishes (14 cm diameter, 1.5 cm height and volume 0.23 l). An aliquot of 0, 2.5, 5, 7.5, 10, 20, 50, 80, 100, 120, 150 and 200 μl of oil was applied to the filter paper discs, corresponding to dosages of 0, 0.016, 0.032, 0.048, 0.07, 0.14, 0.32, 0.52, 0.65, 0.78, 0.97 and 1.30 μl cm^{-2}. Fifty unsexed maize weevil adults were used separately in each dish and these were kept in darkness in the laboratory at 25 ± 1°C and 70–75% rh. Each treatment was replicated at least three times. Insect mortalities were analyzed after 24 h. The percentage of insect mortality was calculated using the Abbott correction formula for natural mortality in untreated controls[17].

Assessment of lethal doses and repellency bioassay

The different 50% lethal doses (LD_{50}) were calculated using linear regression analysis, at 24 h, based on the above-mentioned experimental data, i.e. contact toxicity on filter paper[18].

After that, the effect of on insect mortality against time (0, 4, 8, 12, 24, 48 and 72 h) at the lethal doses (LD_{50}) was studied. The treatment was replicated five times in similar conditions to those used in the study of contact toxicity on filter paper.

The effects of essential sassafras oils against maize weevils were evaluated five times in the repellency bioassay. The repellent action of the essential oils was determined using a system comprising five Petri plates (diameter = 14 cm, 153.9 cm^2), codified as A, B, C, D and E. To plates A and B, 20 g maize with different aliquots (10, 20, 50, 80 and 100 µl) corresponding to dosages of 0.065, 0.130, 0.325, 0.520 and 0.659 $\mu l\,cm^{-2}$ of the essential oils, were added. To plates C and D (blanks), only the substrate was added; and 50 adult maize weevils were added to the central plate (E). After 24 h the number of insects in each plate was counted. Each plate was kept in darkness at 25 ± 1°C and 70–75% rh. Aiming at comparing the different treatments, the preference index (PI) was established, as cited by Procópio et al.[19], defined as:

$$PI = \frac{\%\text{ of insects of test plants} - \%\text{ of insects of blank experiment}}{\%\text{ of insects of test plants} + \%\text{ of insects of blank experiment}}$$

where a PI of −1.00 to −0.10, indicates test plant repellent; PI of −0.10 to +0.10, test plant neutral; and PI of +0.10 to +1.00, test plant attractant.

Repellency bioassay simulating small bins

The values of the effect of essential sassafras oils against maize weevil were evaluated five times in the repellency bioassay (similar to that previous described). However, in this case, the repellent action of the essential oils was determined using a system containing five small glass bins (diameter = 4.5 cm, height = 6 cm, and total area = 95.4 cm^3), codified as A, B, C, D and E. To bins A and B, 80 g maize with different aliquots (50, 100, 150, 250, 400 and 500 $\mu l\,bins^{-1}$) corresponding to dosages of 0.52, 1.04, 1.57, 2.62, 4.19 and 5.24 $\mu l\,cm^{-3}$ of the essential oils, were added. To bins C and D (blanks), only the substrate was added; and 50 adult maize weevils were delivered to the central bin (E). After 24 h the number of insects in each bin was counted. The treatment was replicated five times in similar conditions to those used in the contact toxicity on filter paper experiment. Each small glass bin was kept in darkness at 25 ± 1°C and 70–75% rh. Aiming at comparing the different treatments, the PI was established as cited by Procópio et al[19].

Statistical analysis

Data were analyzed by analysis of variance (ANOVA). Mean separation was determined by the Tukey's test at a confidence level of 95%.

Table 1. Efficiency of insecticidal activity at different doses of essential oil of sassafras against maize weevil in stored maize grains in 24 h.

Concentration (µl/Petri dishes)	Concentration ($\mu l\,cm^{-2}$)	Mortality (%)*
0	0	0 ± 0^{f}
2.5	0.016	0.7 ± 1.2^{f}
5	0.032	15 ± 2.3^{e}
7.5	0.048	42 ± 4.0^{d}
10	0.07	53 ± 3.1^{c}
20	0.14	66 ± 5.3^{b}
50	0.32	86 ± 6.9^{a}
80	0.52	92 ± 5.3^{a}
100	0.65	95 ± 2.6^{a}
120	0.78	95 ± 0.6^{a}
150	0.97	96 ± 2.3^{a}
200	1.30	90 ± 2.0^{a}

* Means (standard deviations) without a common letter are significantly different at 95% confidence level (Tukey's test).

Results and Discussion

Chemical constituents of the essential oils

In general, aromatic plants contain essential oils in concentrations of about 1–3 wt%[20]. In this work, the yield of the essential oils obtained by hydro distillation was 2.6% (v/w) for sassafras. The essential oils, as already mentioned in the literature, can have different concentrations according to genetic, physiologic and climatic factors, the kind of soil and extraction technique[21].

The results of the chemical analysis of each essential oil tested showed that the major constituents of the essential oils from leaves of sassafras were camphene (6%), mircene (1%), β-pinene (0.8%), limonene (3%), camphor (43%), safrole (42%), germacrene (1.2%) and spatulenole (2%).

The results obtained in this work are similar to those presented in the current literature[21]; some differences could be attributed to the collection time, since medicinal species can present different concentrations of some compounds at different times of the year or development stages[22].

Filter paper contact toxicity

Table 1 shows the results in terms of the efficiency of insecticidal activity at different doses of essential oil of sassafras against maize weevil in stored maize grains. The essential oils of the sassafras caused about 86% mortality in concentrations of 0.32 $\mu l\,cm^{-2}$, after 24 h of exposure.

The results obtained here can be considered interesting when compared with others presented in the literature. Tapondjou et al.[23] showed that 1.56 $\mu l\,cm^{-2}$ of essential oil of *Eucalyptus saligna* was necessary to obtain 100%

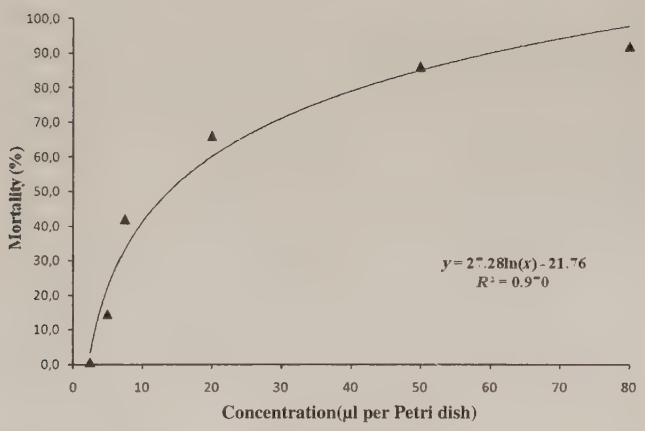

Figure 1. Mortality of maize weevil at different concentrations of sassafras oil at 24 h. The regression data were used to estimate the LD_{50} value.

mortality of *S. zeamais* on the fourth day of exposure, and 0.78 µl cm^{-2} of the essential oil of *Cupressus sempervirens* caused 100% mortality on the fifth day.

The LD_{50} value for sassafras essential oil against the maize weevil was 14.1 µl or 0.09 µl cm^{-2}. In the probit analyses, the calculated regression line equation[18] for maize weevil mortality was $y = 27.284\ln(x) - 21.764$ ($R^2 = 0.97$), the results are shown in Fig. 1.

The results obtained here are very promising when compared with those obtained by other authors. According to Tapondjou et al.[23], the eucalyptus oil presented lower toxicity compared with cupressus oil to both insect species ($LD_{50} = 0.36$ µl cm^{-2} for maize weevil and 0.48 µl cm^{-2} for *Tribolium confusum*) on filter paper discs. These authors observed that the contact toxicity assayed by impregnation of these chemicals on filter paper discs, or coating onto maize grains, caused significant mortality of the evaluated insects.

The study of the effect on insect mortality of lethal doses (LD_{50}) showed that after 72 h a similar mortality of about 100% was observed. These results are presented in Table 2.

Coitinho et al.[24], testing essential oils of different vegetable species, observed that the oil of *Eucalyptus globulus, Lippia gracillis* Schaer (Verbenaceae) and *Azadirachta indica* A. Juss. (Meliaceae) at a dosage of 50 µl/20 g presented higher toxicity, causing 100% mortality of adults of *S. zeamais* in maize grains. Mossi et al.[8] obtained for *Eucalyptus dunni* and *E. saligna* LD_{50} values of 0.16 and 0.25 µl cm^{-2}, respectively, showing lower toxicity than sassafras essential oils (0.09 µl cm^{-2}).

Dunkel and Sears[25] determined toxicity of essential oil vapors from *Artemisia tridenata* Nutt. ssp. vaseyana (Rydb.) against *Rhyzopertha dominica* and found that 1,8-cineole and camphor are the major agents of toxicity. Yan et al.[26], observed that *S. zeamais* Motschulsky and *Tribolium castaneum* (Herbst) adults were equally

Table 2. Effect of a lethal dose ($LD_{50} = 0.14$ µl cm^{-2}) of sassafras essential oil against the maize weevil, for different times.

Time (h)	Mortality (%)*
0	0.0 ± 0^{d}
4	0.0 ± 0^{d}
8	14.7 ± 4.2^{c}
12	23.3 ± 7.6^{c}
24	46.6 ± 2.3^{b}
48	92.0 ± 8.0^{a}
72	100.0 ± 0^{a}

* Means (standard deviations) without a common letter are significantly different at 95% confidence level (Tukey's test).

susceptible to contact toxicity of safrole or isosafrole. Safrole also possessed equal fumigant toxicity to adults of both species. However, isosafrole was generally more toxic than safrole to the insects tested. In flour disk bioassays, safrole showed very slight feeding deterrence against maize weevil adults.

The results obtained here are very interesting and the effect of the essential oil is probably because of the presence of camphor (43%) and safrole (42%), and the synergistic effect of both.

Repellency activity

Based on the PI values (Table 3), the essential oil tested in this work showed efficiency against the adults of maize weevil and a trend of increasing activity with increasing dosage can be seen. The values of the PI varied from −0.39 (0.065 µl cm^{-2}) to −0.63 (0.659 µl cm^{-2}), being lower than −0.10, the minimum limit proposed by Procópio et al.[19] to consider that a plant has repellent activity.

Procópio et al.[19] evaluated the repellent effect of fragments of leaves of six vegetable species against adults of maize weevil and verified, based on the PI, that two species were repellents, the leaves of *Eucalyptus citriodora* (PI = −0.81) and *Capsicum frutescens* (Meliaceae) (PI = −0.17)[19]. Tested eucalyptus oils were highly repellent to the two insect species, *T. confusum* and *S. zeamais*[23].

The highly toxic and repellent effects of some of the other main constituents of these oils, such as camphor and safrole, terpineol and α-pinene, have been demonstrated by other researchers[27–29]. The toxic effects of the essential oil extracts could also be attributed to an enhancement on the effect of some other minor constituents, such as limonene which was previously found to exhibit insecticidal activity against *R. dominica* (F.) and *T. castaneum* (Herbst)[27]. Concerning the mode of action of cymol and essential oil extracts mainly constituted of mono- and sesqui-terpenoids, Ryan and Byrne[30] suggested that the toxic effect may be attributed to reversible competitive

Table 3. PI for the essential oil from sassafras, following the methodology proposed by Procópio et al.[19].

Concentration (µl/Petri dishes)	Concentration (µl cm^{-2})	% of insect		PI*
		Standard (without oil)	Treatment	
10	0.065	69.5±2.5	30.5±3.6	−0.39
20	0.130	74.4±7.8	25.6±6.8	−0.48
50	0.325	72.7±8.1	27.3±6.6	−0.45
80	0.520	77.6±11.4	22.4±8.6	−0.55
100	0.659	81.6±9.8	18.4±8.1	−0.63

* PI of −1.00 to −0.10, test plant repellent; PI of −0.10 to +0.10, test plant neutral; PI of +0.10 to +1.00, test plant attractant.

Table 4. PI for the essential oil from sassafras in small bins, following the methodology proposed by Procópio et al.[19].

Concentration (µl/small bins)	Concentration (µl cm^{-3})	% of insect		PI*
		Standard (without oil)	Treatment	
50	0.36	41.2±1.7	8.8±1.7	−0.64
100	0.72	42±2	8±2	−0.7
150	1.08	44.8±1.7	5.2±1.7	−0.79
250	1.8	46±1.1	4±1.1	−0.84
400	2.9	48.4±1.0	1.6±1.0	−0.94
500	3.6	48.2±0.7	1.8±0.7	−0.92

* PI of −1.00 to −0.10, test plant repellent; PI of −0.10 to +0.10, test plant neutral; PI of +0.10 to +1.00, test plant attractant.

inhibition of acetylcholinesterase by occupation of the hydrophobic site of the enzyme's active centre.

Repellency bioassay simulating small bins

The repellency bioassay simulating small bins presented promising results at all aliquots of tested oils, showing repellent effects that ranged in preference level from −0.64 (0.36 µl cm^{-3}) to −0.94 (2.9 µl cm^{-3}) (Table 4). The results suggest that the essential oil of sassafras could be used against maize weevil on a large scale.

Conclusion

Large quantities of plant material would have to be processed for use on a small scale. However, certain compounds in the oils exhibit stronger activity. In this case, the small farmer could cultivate their own biopesticides. In our study, the essential oil was extracted by hydrodistillation achieving an oil yield of 2.6% (v/w). The chemical composition of the essential oil showed that camphor (43%) and safrole (42%) are major compounds. The results showed that the essential oil caused about 86% mortality at a concentration of 0.32 µl cm^{-2}, after 24 h of exposure. The LD_{50} was 14.1 µl or 0.09 µl cm^{-2}. These results permitted us to conclude that the essential oil of sassafras presented insecticidal and repellent activity against maize weevil. Although from an economical point of view synthetic chemicals are still more frequently used as repellents, natural products (essential oils) have the potential to provide repellents that are efficient and safer for humans and the environment.

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Exploring risk management strategies for organic farmers: A Greek case study

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Abstract

This study attempts to enrich the debate on the different forms of risk management strategies that are utilized by organic farmers and to assess the internal dynamics within the organic farming community by examining the attitudes and practices of these farmers. In particular, using a factor analysis, this study determines the attitudes of Greek farmers toward risk management strategies and focuses on the differences in risk attitudes between existing organic farmers and non-organic farmers. Second, using a probit analysis, this study characterizes the key factors that affect Greek farmers' attitudes with respect to risk management strategies. The thorough presentation of this research study provides essential information to policy-makers for understanding the factors that induce farmers to participate in organic agriculture. Moreover, the analysis of the risk management strategies that organic farmers apply is expected to offer valuable insights that will be critical for the timely introduction and efficient application of the forthcoming post-2013 Common Agricultural Policy (CAP) measures.

Key words: organic agriculture, risk management, agriculture policy

Introduction

In recent years, interest in organic agriculture has grown around the world. Food safety and environmental concerns have increased the public demand for organic products and shifted the organic sector from the economic margins to the mainstream. Applied agricultural policies have offered farmers several incentives to convert to organic production practices, boosted the development of the organic sector and sharply increased the quantity of organically cultivated farmland in the European Union (EU). At present, 7.8 million hectares in the EU-27, almost 4.3% of the total utilized agricultural area of these nations, are farmed organically[1].

However, the importance of organic farming varies among the EU member states. In Greece, the organic sector was relatively unimportant until the mid-1990s (the trade and development of organic products in Europe began in 1993, following the implementation of EU Regulations 2092/91 and 1804/99 for organic crop production and the organic livestock sector, respectively); however, it has undergone rapid growth since that time. In particular, the total land area that has been fully converted to organic farming or is currently under conversion to organic farming practices increased from 591 ha in 1993 to 309,822 ha in 2010, which represents 8.2% of the total utilized agricultural area and approximately 24,000 holdings. In essence, the rapid expansion of the organic market along with the review of the Common Agricultural Policy (CAP), which increased farmers' orientation to the market and strengthened its support to high quality production, paved the way for a rapidly increasing number of Greek farmers to convert to organic. This trend built on the unique opportunities that the Greek landscape and environmental parameters offer especially to the organic cultivation of low input production, well established within the endogenous farming tradition, such as olive oil and fruit products, which enjoyed a price premium in the domestic and international markets and at the same time were satisfying consumers' environmental and food safety concerns.

Several studies have attempted to assess the reasons that drive farmers to adopt or avoid organic farming[2–15]. These investigations have identified a wide range of factors that are associated with the adoption of organic farming; however, researchers generally agree that diverse answers are obtained to the question of 'how' and 'to what extent' each of these factors affect organic conversion. Parameters that can explain why farmers decide to adopt organic farming practices include not

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only the personal characteristics of these farmers and various structural factors but also diverse economic, environmental, institutional, social and health considerations. Most studies describe organic farmers as better educated and younger than the conventional ones, while they generally own smaller farms and have limited farming experience. Among other motivations, economic factors (such as better prices, increased demand and market potential for organic products) and non-economic factors (such as lifestyle choices that relate to environmental and health concerns) are reasons that farmers assume the risks of converting to organic production practices.

In contrast to the relatively limited number of factors that encourage farmers to adopt organic practices, a wide range of obstacles to organic conversion has been identified in the literature[3,12,14,16–20]. In particular, concerns about production difficulties, income variability, marketing issues, fragmentary and scarce technical support, high production costs, the high volumes of paperwork that are involved in enrolling in subsidy programs and the management of uncertainty are factors that prevent the adoption of innovative farming systems, such as organic agriculture. As organic farming is highly exposed to risk, the choice of rational risk management tools is a fundamental determinant of the long-term viability of this farming system[8,13,21–23].

In Greece, most of the research efforts that have addressed organic agriculture have focused on either economic and technical efficiency[24–26] or consumer preferences[27–29], and several studies have addressed the issue of farmer participation in agri-environmental programs[30–32]. However, there is a clear dearth of research that examines the motives, goals and risk management strategies of Greek organic farmers. Therefore, the objective of this paper is twofold: (a) to determine the motives and the goals that are associated with the adoption of organic agriculture and (b) to determine the risk management strategies that are applied by organic farmers in Greece. This study seeks to enrich the debate on the different forms of risk management strategies that are utilized by farmers and to characterize the attitudes and practices that are related to the internal dynamics of organic farming. First, through a factor analysis, we attempt to determine the attitudes of Greek farmers toward risk management strategies, focusing on the differences in risk attitudes between organic farmers and non-organic farmers. We examine the perspective of farmers as innovators through the risk management strategies they employ and compare the risk tolerances of organic and non-organic farmers. Second, through a probit analysis, we attempt to explain the key factors that affect the attitudes of Greek farmers with respect to various risk management strategies. The thorough nature of this investigation provides essential information to policy-makers that will further their understanding of the factors that induce farmers to participate in organic agriculture. Moreover, this study reveals relevant approaches and issues for further research efforts.

The remainder of this paper is arranged as follows. The next section of the paper presents the materials and statistical methods that are used in this study. Then, survey data are presented and critical dimensions of the sample are discussed. Subsequently, the results of the empirical application are discussed and analyzed to determine the factors that influence the participation of Greek farmers in organic agriculture and the risk management tools that these farmers utilize. Finally, the paper concludes with a summary of the main findings of this investigation and the policy implications that can be derived from these results.

Methodology

Farmers' perceptions of risk and risk management strategies were initially examined through descriptive analysis. In particular, a survey was administered to a stratified random sampling of 72 organic and 51 conventional farmers that asked respondents to identify sources of risk and to use Likert scales to rate items that related to risk management strategies. Basic statistics, such as the mean values of the survey responses, were compared for organic and conventional farmers, using standard *t*-tests for metric (quantitative) variables and chi-square tests for non-metric (qualitative) variables. SPSS (SPSS Inc., Chicago, Illinois, USA) was used to perform the data analysis. Furthermore, a factor analysis was employed; this technique is a well-established approach that has been utilized in the literature to assess similar data and outcomes[8,10,13,14,18]. Principal component analysis was then applied to reduce the number of factors and summarize the information that had been obtained about perceptions of risk management strategies. The factor solutions, obtained through the orthogonal varimax rotation of different number of factors, were examined to determine the most characteristic and reliable set of factors. Standardized factor scores for each farmer and each factor were introduced into the subsequent probit analysis.

In an analysis involving a choice between two alternative options, probit analysis is used to quantify the relationship between the probability of selecting one of these alternatives (a number between zero and one) and various characteristics that affect this choice[33]. The probit model uses the functional formula of Prob $[y_t = 0] = 1 - \Phi(x_t\beta)$, where $\Phi(\bullet)$ is the cumulative normal distribution; that is, $\Phi(z)$ is the probability that a random variable with a normal distribution, zero mean and unit variance does not exceed z. The dependent variable is not continuous but is instead a dichotomous binary variable, i.e., either an organic or conventional farming system. The probability depends on a vector of independent variables (x_t) and a vector of unknown parameters β. The task

Table 1. Descriptive data.

Farmer and farm characteristics	Organic	Conventional	Total
Gender (% male)	81.9	94.1	87.0
Age (% <40 years old)	26.4	25.5	26.0
Education (% post-secondary)	18.1	9.8	14.6
Agricultural training (% yes)	27.8	15.7	22.8
Farming experience (% yes)	97.2	98.0	97.06
Size [area in 0.1 ha, presented as the mean (SD)]	97.4 (69.2)	96.5 (48.3)	97.0 (61.2)
Risk attitudes			
Production risk (mean)	*5.97	3.96	5.14
Marketing risk (mean)	5.67	5.51	5.60
Financial risk (mean)	4.67	4.86	4.75

* Indicates significance at $P<0.05$.

of the estimation is to determine the best values for these parameters. As it is assumed that $x_i\beta$ is normally distributed, interpreting probit coefficients requires assessing the data in terms of the Z metric. The interpretation of a probit coefficient, β, is that a one-unit increase in a predictor increases the probit score by β standard deviations. The estimation of a probit model is obtained by maximizing the likelihood function. This maximization requires an iterative method; however, in most cases, these iterations operate smoothly because probit functions are remarkably well behaved. Goodness of fit and inferential statistics are based on the log likelihood and chi-square test statistics.

Data

The data that are used for this research are obtained from a survey that was administered in 2010 in the Lakonia area of the Peloponnisos region of Greece. Lakonia is one of the most prominent areas in Greece for organic agriculture, containing 15,851 ha of organically cultivated farmland. In fact, Lakonia is the Greek area with the highest percentage of organic agriculture, and it accounts for 15.9% of the total Greek land area that has been converted to organic farming. The primary crops that are grown in Lakonia are olives (76.8%), citrus fruits (3.9%), nuts (2.4%) and forage crops (0.2%). This very production profile within the prefecture reflects also the structure of the organic output at the national level[34], which was an additional reason for the selection of Lakonia as the field area under study, despite the fact that its landscape may not be considered as representative for the country as a whole.

The aim of the survey was to examine farmers' attitudes with respect to both the primary sources of risk for organic farming and the application of risk management strategies. A stratified random sampling method involving Neyman optimum allocation was employed for the survey which returned a survey sample of 72 organic farmers and 51 neighboring conventional farmers. The organic subsample was drawn from the population of 1046 organic farmers active in the area which was stratified according to their main productive direction, the duration under certificated organic production and the acreage of the farm. For the conventional farmers' subsample, a two-stage sampling procedure was followed. In the first stage, four rural municipalities were randomly selected from the stratified list of 20 dynamic, less-favored and mountainous municipalities of the prefecture. Conventional farmers within selected units were stratified according to their productive direction and farm size and a random selection was conducted. As this survey included a small sample size, its research findings are considered to be exploratory in nature. To collect the survey data, a questionnaire was administered during personal interviews with the survey respondents. The questionnaire included questions regarding the following topics: (a) the socio-demographic characteristics of the farmer; (b) the physical characteristics of the farm; (c) the farmer's perceptions of risk and of risk management strategies; and (d) the farmer's goals, future plans, motives and knowledge about organic agriculture.

The survey revealed that organic and conventional farmers had similar mean ages, as the average ages for the organic and conventional farmers who were surveyed were 48 and 50 years, respectively (Table 1). However, the percentage of farmers who were less than 40 years old was slightly higher for organic farmers (26.4%) than for conventional farmers (25.5%). In accordance with the social standards of Greek society, farmers of both types were generally married with two children. Organic farmers were better educated; in particular, 18.1% of the organic farmers but only 9.8% of the conventional farmers had acquired a post-secondary education. In addition, there was no significant difference between the two farming groups with respect to the size of the farmed land. Organic farmers had more agricultural training and farming experience due to family tradition in the sector, indicating that they possessed a higher quality of human capital. Agriculture was the main activity for both types of farmers, although a higher percentage of organic farmers

Table 2. Motives for engaging in organic agriculture.

Motives	Org mean	Con mean	Org rank
Subsidies	6.28	6.59	1
Environmental protection**	6.28	5.43	2
Better prices*	6.14	5.61	3
Organic agriculture uses less fertilizers and chemicals**	6.06	3.90	4
My cultivation is less effective with reduced use of chemicals**	5.94	3.76	5
Organic neighborhood networking**	5.01	2.94	6
Increased demand for organic products**	4.24	3.51	7
Organized marketing chains**	4.24	3.51	8

* and ** indicate significance at $P<0.05$ and $P<0.001$, respectively.

(30%) than conventional farmers (9.8%) were engaged in off-farm work. Organic farmers were more willing than conventional farmers to take further production risks as they feel more confident about production changes due to the experience they accumulated during their transition to organic.

The decision to convert to organic farming involves several types of complex motivations. For organic farmers, the most important motives included both economic and environmental considerations, followed by social motivations (Table 2). In particular, the most highly ranked motives were the subsidies that were provided for organic farmers and a desire to protect the environment. Better prices for organic products and the low needs of olive trees for fertilizers and chemicals prompted farmers to adopt organic agricultural practices. These findings are in accordance with the results of Rigby *et al*[5]. and Lapple and Donnellan[35], who stressed that farmers' decisions with respect to converting to organic farming were likely to be motivated by economic considerations and by social networks. Good relationships with neighborhood networks that related to organic farming were a critical factor that positively affected farmers' attitudes toward adopting organic agricultural practices in the Lakonia area, confirming the results of other relevant studies[6,12,31,36–38]. Finally, increased demand and organized marketing chains were also among the determinants of the adoption of organic agriculture. Conventional farmers have nearly the same attitudes as organic farmers about the aspects of organic farming that relate to subsidies, prices and environmental protection. In contrast, conventional farmers provided significantly lower ratings than organic farmers for the factors of social networking and organized marketing channels; this result indicated the negative attitude of conventional farmers with respect to these considerations.

Analysis and Results

Factor analysis

Farmers' opinions of 19 risk management strategies were acquired. Each of these strategies was rated on a Likert scale that ranged from 1 (not relevant) to 7 (very relevant), and the results of these rankings are reported in Table 3. The most preferred strategies for organic farmers are to produce at the lowest possible production cost and to take advantage of opportunities to seek for professional consulting about the economic and bureaucratic aspects of organic farming. The provision of information about organic farming is a crucial issue for these farmers; this information produces positive effects on farm diversification. Moreover, organic farmers seek to save money and prefer to possess increased liquidity because this flexibility offers them greater freedom of action during the current economic recession in Greece. Small and gradual changes in production, the use of agronomic consultants to assist in preventing and reducing crop diseases, and farm business insurance tools are also critical risk management strategies of farmers. Organic farms are not highly diversified but instead follow regional specializations, implying that farmers adopt an 'input substitution' approach rather than a 'system redesign' approach to organic farming[39]. The primary goals of organic farmers are profit maximization and continued agricultural activity; therefore, these farmers utilize rational tools to diversify their income. Organic farming offers these farmers the opportunity to improve their product quality and obtain better prices. In addition, organic farmers use alternative distribution channels and methods to sell their products; in particular, direct sales and storage options that yield better prices are the dominant strategies of organic farmers, whereas traditional agricultural strategies, such as collaboration in local cooperatives and debt management, are the approaches that are ranked lowest by organic farmers.

The most preferred risk management strategies among conventional farmers are flexible storage; small and gradual changes in production; off-farm work; the ability to save money by liquidating assets; cooperation through partnerships; and low cost production. Conventional farmers were not familiar with the use of consultancy services, insurance measures and product contracts, but they would like to use local cooperatives to distribute their products.

A factor analysis of the 19 risk management strategies that were presented to the survey respondents, using principal component extraction combined with a varimax

Table 3. Perceptions of risk management strategies.

Risk management strategies	Org mean	Con mean	Org rank	1	2	3	4	5	6	7
Producing at the lowest production costs	6.53**	5.76	1	0.004	0.126	−0.002	0.005	0.173	0.219	**0.807**
Consultancy (economic and bureaucratic aspects of farming)	6.31**	4.29	2	d	d	d	d	d	d	d
Liquidity (to save money)	6.17	5.98	3	0.169	0.237	0.212	0.112	**0.701**	−0.006	0.003
Flexibility of storage	6.00*	6.53	4	**0.700**	−0.279	0.009	0.227	−0.107	0.299	−0.127
Liquidation of assets	5.86	5.80	5	**0.731**	0.006	0.156	0.208	0.194	−0.124	0.001
Small and gradual changes	5.82	6.08	6	0.005	−0.003	−0.007	**0.729**	0.161	0.110	−0.003
Prevent and reduce crop diseases and pests	5.67	5.73	7	0.183	0.005	**0.781**	0.002	−0.000	0.273	−0.183
Off-farm work	5.61	5.92	8	0.123	**0.721**	0.171	0.004	−0.007	0.183	0.103
The use of agronomic consultants/services	5.56	5.37	9	0.003	0.005	**0.882**	0.003	0.151	−0.001	0.005
Weather risk-reducing technologies	5.11	3.94	10	d	d	d	d	d	d	d
The purchase of farm business insurance	5.06**	3.59	11	−0.005	−0.138	0.000	−0.003	**0.737**	0.112	0.002
Cooperation in partnerships	4.93**	5.76	12	0.168	0.127	0.144	**0.754**	−0.133	−0.006	−0.008
Product market flexibility	4.68	4.59	13	−0.002	0.003	0.125	−0.002	0.104	**0.877**	0.105
Off-farm investments	4.60	4.94	14	**0.681**	0.427	−0.001	−0.156	−0.000	0.004	0.157
Investments in land and machinery	4.50	4.35	15	d	d	d	d	d	d	d
Cooperative or PO Marketing	4.25**	5.06	16	−0.001	**0.736**	−0.003	0.005	0.005	−0.002	−0.183
Solvency and debt management	4.10*	4.53	17	−0.003	0.315	0.350	0.409	−0.425	−0.002	0.284
Enterprise diversification (crops and activities)	3.85	4.96	18	0.000	0.310	0.007	0.227	0.161	0.103	**−0.668**
Product contracts	3.82	3.94	19	0.418	0.377	0.105	0.159	−0.006	**0.562**	0.003

The mean values that are marked with * and ** indicate that the scores of organic and conventional farmers are significantly different at $P<0.05$ and $P<0.001$, respectively, based on independent sample *t*-tests.
The 'd' entries indicate that the variable has been deleted from the factor analysis because of its low Kaiser–Meyer–Olkin measure (KMO) or low communality.

rotation, resulted in seven factors with eigenvalues that were greater than 1. Two risk management options (e.g., weather risk-reducing technologies and investment in land and machinery) have been omitted from the factor analysis because they had insignificant mixed factor loadings. The Kaiser–Meyer–Olkin measure of sampling adequacy was 0.663 for the entire set of variables, suggesting that the matrix was suitable for factor analysis. In factor analysis, any factor loadings that are greater than 0.30 are considered to be significant factors. Factor loadings that are greater than 0.40 are considered to be relatively important, whereas loadings that are greater than 0.50 are considered to be highly significant; the latter types of factor loadings are examined in this study[40].

The seven-factor solution generated the most interpretable factors and was therefore judged to be the most useful solution that was generated by the factor analysis. Standardized factor scores for each farmer were recorded and used for subsequent multivariate analyses. These factors explained 67.8% of the total observed variation. Table 3 displays the seven factors and their respective loading items. Factor 1, which was named *flexibility*, explained 19.92% of the observed variation and had high loadings for the items of flexibility of storage, liquidity of assets, and off-farm investments. Factor 2, which explained 9.58% of the observed variation, was named *traditional income improvement strategies* because the dominant variables for this factor are off-farm work and cooperation with a local cooperative. Factor 3, which explained 9.21% of the observed variation, was named *consultancy* and included the dominating variables of the use of agronomic consultants/services and measures to prevent and reduce crop diseases and pests. Factor 4, which explained 8.30% of the observed variation, was named *gradual changes* and included the two dominant variables of cooperation in partnerships and small and gradual changes. Factor 5, which explained 7.83% of the observed variation, was named *insurance* and referred to the variables of buying farm business insurance and the ability to save money through maintaining high liquidity. Factor 6, which explained 6.58% of the observed variation, was named *marketing strategy*, referred to product market flexibility and product contracts. Finally, factor 7, which explained 6.36% of the observed variation,

Table 4. The definitions of the variables that are used in the probit model.

Variable	Description
Dependent	
	1 = Organic, 0 = Conventional
Independent	
Farmer characteristics	
Gender	1 = Male, 0 = Female
Age	1 = Farmers who are less than 40 years of age; 0 = other farmers
Education	Has the farmer received a post-secondary education; 1 = Yes, 0 = No
Agricultural training	Agricultural training (seminars); 1 = Yes, 0 = No
Farming experience	Are you coming from an agricultural family; 1 = Yes, 0 = No
Size	Farm size (in 0.1 ha)
Risk attitudes	
Risk 1	Production risk; 1 = Yes, 0 = No
Risk 2	Marketing risk; 1 = Yes, 0 = No
Risk 3	Financial risk; 1 = Yes, 0 = No
Risk management strategy factors	
Factor 1	Flexibility
Factor 2	Traditional income improvement strategies
Factor 3	Consultancy
Factor 4	Gradual changes
Factor 5	Insurance
Factor 6	Marketing strategy
Factor 7	Aspects of production cost

was named *aspects of production cost* and incorporated the focus of farmers on low production costs and on improving the diversification of their enterprises.

Probit analysis

The probit model was estimated using a standard maximum likelihood approach. The dependent variable for this model was the adoption (or lack thereof) of organic farming. In particular, the binary-dependent variable takes the value of 1 if the respondent is an organic farmer and 0 for a conventional farmer. The tentative explanatory variables include both continuous and binary variables and are presented in Table 4. Three categories of variables were included in the probit analysis: farmer characteristics, risk attitudes and the factors from the factor analysis of risk management strategies. The maximum likelihood estimates of the probit model are presented in Table 5. The model results indicate that 82.9% of the observations were correctly predicted. According to the model chi-square statistic, the overall model is significant at the 0.000 level (72.133), and its McFadden R^2 is equal to 0.432. Both of these goodness of fit measures indicate that the probit model performed reasonably well, particularly given the cross-sectional nature of the analyzed data.

The probit results revealed that the experience in agriculture is a vital factor that positively affects farmers' attitudes toward adopting organic agriculture. Farmers with high levels of experience in agriculture are almost 71% more likely to produce organically. This result can be related with the findings regarding attitudes about production risk. Farmers who would like to take production risks are 66% more likely than risk-averse farmers to shift to organic agricultural practices. These results imply that agricultural experience may provide farmers with the confidence to employ an input substitution approach and successfully address the additional production risks that accompany the learning of new organic farming procedures. These farmers' long-term involvement with agriculture causes them to feel positive about assuming the risks of organic production procedures. Among the other farmer characteristics that were examined, gender, age, education, agricultural training and farm size were not found to be significant determinants in explaining the participation of farmers in organic farming. Most previously published studies of organic farming have identified age as a powerful factor that influences conversion to organic farming practices. In our case, there is a negative relationship between age and organic farmers. This result supports the hypothesis that a decreased willingness to participate in an organic farming system is generally associated with older farmers. As demonstrated by several relevant studies[6,10,41], young farmers with education and agricultural training are more willing to take risks.

The ability to utilize a main risk management strategy of reducing production costs and the adoption of a positive attitude toward applying production innovations positively affect (29%) farmers' decisions to adopt organic farming practices. Organic farmers use rational approaches to maximize their income and to maintain their agricultural activities. The dimension of producing at the lowest cost does not refer to certification costs but instead accounts for the knowledge and application of optimal production cost management approaches for reducing production inputs and addressing all of the new changes that are required by an organic regime.

The ability to face the difficulties and the wide variety of risks that are involved in organic agriculture drive organic farmers to use insurance as a risk management strategy for their farm. The use of insurance tools has a positive effect (a marginal effect of 0.2930) on the adoption of organic agriculture. The use of insurance and the wise management of economic outputs, such as the tendency to save money to account for future risks, an extensive knowledge of production issues, and experience with marketing problems, appear to drive farmers to engage in organic agriculture. As expected, the strategy of small and gradual changes is not suitable for innovative farmers, including organic farmers; thus, it is unsurprising that the

Table 5. The estimation results of the probit model.

	Coefficient	Standard error	Marginal effects	Standard error
Intercept**	−2.6581	1.1224	−1.0318	0.4422
Gender	−0.1914	0.4736	−0.0743	0.1836
Age	−0.0849	0.4814	−0.0329	0.1870
Education	0.6527	0.4907	0.2533	0.1909
Agricultural training	0.5303	0.4642	0.2058	0.1811
Farming experience**	1.8338	0.9964	0.7118	0.3857
Size	0.0016	0.0031	0.0006	0.0012
Risk attitudes				
Risk1: Production risk*	1.7000	0.4714	0.6599	0.1883
Risk 2: Marketing risk	−0.3318	0.5154	−0.1288	0.2001
Risk 3: Financial risk	0.0570	0.3339	0.0221	0.1296
Risk management strategies				
Factor 1: Flexibility**	−0.4244	0.1882	−0.1647	0.0727
Factor 2: Traditional income improvement tools *	−0.5624	0.1894	−0.2183	0.0740
Factor 3: Consultancy	−0.0869	0.1661	−0.0337	0.0644
Factor 4: Gradual changes**	−0.3349	0.1715	−0.1300	0.0666
Factor 5: Insurance*	0.7549	0.2030	0.2930	0.0773
Factor 6: Marketing strategy	0.0281	0.1688	0.0109	0.0655
Factor 7: Production cost*	0.7640	0.2761	0.2965	0.1090
Model chi-square	72.133			
McFadden's *R*	0.432			
% of correct predictions	82.9%			

* and ** indicate significance at the 0.01 and 0.05 levels, respectively.

employment of this type of strategy was associated with a negative effect on the adoption of organic agricultural practices (marginal effect −0.1300). Finally, traditional strategies to improve farmers' income, approaches that focus on the use of flexible post-harvest management and investments in assets outside of agriculture are factors that produce negative effects on the adoption of organic agriculture.

Conclusions

The present exploratory study sought to reveal the primary risk management strategies that would facilitate the development of organic farming in Greece. Economic and environmental parameters, as well as social networking effects, explain the immense development of organic farming in the study area. Our results suggest that organic farmers perceive themselves as risk-friendly with respect to the production challenges of organic farming systems but that they may also be regarded as rational and pragmatic individuals who follow sustainable and viable farming strategies. The use of information is a crucial and valuable aspect of their management decisions. Thus, their management strategies involve using new tools, such as the purchase of insurance and the use of consulting resources for agronomic and/or economic aspects of organic farming, before committing to a final decision to engage in organic farming. The enrichment of these two specific needs of organic farmers should be a significant concern for policy-makers in their attempts to improve the institutional framework of agriculture. The development of well-defined and appropriately designed insurance tools and the improvement of the advisory system for farmers are considered necessary features of institutional initiatives to support Greek farmers, particularly in the current environment of uncertainty that prevails in Greece. The forthcoming post-2013 CAP is expected to incorporate these types of measures to increase the productivity and the competitiveness of the agricultural sector. The improvement of the agricultural advisory system and the creation of rural networks will facilitate knowledge creation and transfer, benefiting organic farmers. Moreover, as indicated by the results of this study, the provision of incentives to utilize risk management instruments and active prevention strategies is a policy direction that Greek organic farmers will certainly welcome. This last point is of considerable importance in the midst of the crisis as farmers are all the more focusing on new demanding productive options such as organic vegetables and organic livestock production. At the same time, the low-input set of currently available organic activities, such as olive oil and fruit products, is also enlarged to include organic fodder, to support organic livestock needs, and new fruit categories which face a promising future, especially in international markets.

Although the sustainability development aspect of EU policies has traditionally promoted organic agriculture,

improvements to the institutional framework supporting organic agriculture appear to be urgently required. One of the greatest challenges at the present time is to construct a new policy framework that includes not only traditional policy targets but also a wide plethora of new policy objectives, such as maintaining natural capital, sustaining life support systems, minimizing human impact, developing human capital, increasing social capital, promoting economic growth and creating institutions[42]. Many of the aforementioned parameters are strongly connected to the organic farming system. Organic, high-quality products constitute an important aspect of Greek agriculture; given that Greek farmers are increasingly near the epicenter of a new 'production model' for Greece, policy-makers should provide necessary institutional support to organic farming by implementing the anticipated new CAP measures in a timely and cautious manner. Such initiatives should also couple the necessary institutional and legal improvements within the domestic supply chain in order to increase the market potential of organic products[26,43,44]. The creation of a meaningful value chain based on organic output of high quality is considered essential in order to put a dynamic part of the Greek agricultural sector on a sustainable and profitable future and to satisfy at the same time consumers' concerns and access to foods of high nutritional value.

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Feeding a population with smaller scale and alternate system production: An examination of farm requirements with a multi-species pasture system to feed 10 million people

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Abstract

Current agricultural and food systems literature suggests multiple opportunities for improving systemic sustainability. Especially in the popular press, many authors have conceptualized a return to smaller scale diversified production as a strategy to feed America sustainably. This study explores this notion for components of our meat supply using approaches reported in one of the most popular of these books, Michael Pollan's *The Omnivore's Dilemma,* as a touchstone. We examine the land footprint and number of farms required to produce beef, chicken and eggs for the state of Michigan (a population just under 10,000,000) using similar production strategies to those outlined in Pollan's book. To feed Michigan's population at a scale of production demonstrated on the highlighted farm in Pollan's book, and an average level of Midwest intake for beef, chicken and eggs would require approximately 3600 farms and 6.5 million acres of farmland to produce 100% of the beef, 100% of the eggs and about 50% of the broiler chickens for this population. The strategy is discussed in reference to existing farms and acreage in Michigan and put in the context of sustainability within our food supply.

Key words: consumption patterns, grain-based, grass-finished, liveweight, multi-species pasture rotation systems (MSPR), pasture-based

Introduction

There is an extended narrative in the academic and popular press providing support and critique of both 'alternative' and 'industrial' agricultural systems. Animal agriculture is discussed in a wide range of disciplines in relation to animal welfare issues[1], environmental impacts[2,3], human health risks[3,4] and new methods of production[5,6], among others. There has also been an increase in studies on grass-finished beef production as well as the pasture-based production of broilers and laying hens. Many of the grass-finished beef production studies are surveys or analyses of current producer conditions and potential for market/production growth[7–10]. Studies regarding pasture-based poultry systems are few and limited in scope. Most focus on poultry feed consumption in pasture systems[11–13]. Multi-species pasture rotation systems (MSPR) have not been systematically researched.

In the past 20 years, there has been market growth for alternative agriculture production system products, such as organic and pasture-based proteins[14–16]. This consumer movement has spawned a body of literature and documentaries that scrutinize conventional agriculture practices[17]. These books and documentaries also typically profile proposed alternatives, often without an equally detailed look at their sustainability and implications for a system-wide shift to these production strategies. Probably the two most influential popular books of the 21st century to date in this regard are *Fast Food Nation*[18] and *The Omnivore's Dilemma*[19]. It was Pollan's uneven treatment of various agricultural systems in *The Omnivore's Dilemma* that inspired our research. This study used Michigan as an

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examination site to geographically bind the study with a manageable scale of population (< 10 million people, approximately 3% of the US population) and a relatively uniform climate. The question then was posed: how much acreage and how many farms would it take to produce enough beef, chicken and eggs locally for the state's population? While the pasture-based farm profiled by Pollan produces more products than beef, chicken and eggs (also turkey, pork and rabbit) we are not considering them in this analysis. The animals (cows and chickens) included in our present analysis share the most acreage and present a fairly complicated model as is. To complement this question, the acreage necessary to produce these same products from grain-based systems for Michigan was also calculated.

Pasture-based systems are often promoted because of their perceived benefits to society, environment, health and quality of life of farmers[7,15,20,21]. The purpose of this paper, however, is not to argue for or against pasture-based production but to analyze this MSPR system (cattle and chickens) and identify what scale of change might be necessary if it became a large part of the meat production supply.

We are not aware of any research to date estimating the land and farms required to feed a population in relation to these types of production systems; however, numerous studies have attempted to estimate the land requirements relative to food consumption patterns. Most studies investigate the effect of different food consumption patterns on the agricultural land requirements. Conner et al.[22] incorporated an estimation of land into their economic analysis of the effects of developing more local fruit and vegetable production in Michigan. Various papers look at current consumption patterns or a range of other consumption patterns in relation to the acres required to produce this food[23–26]. These papers contain no analysis of different production systems; rather the emphasis is on different dietary patterns with a generic production system. These papers are quite similar in concept to the following analysis; however, consumption levels were held constant and the potential production per acre of two different production systems was examined.

Methods

Multiple information sources were used to estimate the amount of land and number of farms required to produce enough beef, chicken and eggs for the population of Michigan. For this study, MSPR production levels similar to Polyface Farm (as outlined in Pollan's *Omnivore's Dilemma* and through personal communication) in northern Virginia were assumed for Michigan, an assumption verified by consulting USDA averages, industry specialists and a local farmer. A sequential analysis was conducted that included: annual Michigan per capita beef and poultry consumption levels, the animal nutrition/feed requirements in both pasture and grain-based systems to produce beef, chicken and eggs, and the acreage necessary for animal feed. The use of non-peer reviewed data was limited to the extent possible.

Consumption and meat requirements

Product disappearance data were used as a surrogate for annual consumption[27] and beef average consumption was modified to reflect a Midwest regional difference[28]. Total consumption, used as the annual population demand, was then calculated using Michigan population data[29]. These consumption levels assume a year-round supply of beef for the consumer. It may be problematic for non-frozen beef to be available off-season[10] as there are difficulties finishing cattle throughout the year on grass.

The number of cattle needed was determined from the average slaughter liveweights and converted to average pounds of saleable meat per head of cattle. The average slaughter liveweight for the grass-finished system was taken from a survey of grass-finished beef producers[30]. Fifty-six percent of the slaughter liveweight, the industry average for grass-finished beef, was used to calculate the carcass weight (Dr A. Williams, personal communication, February 25, 2011). The carcass yield (edible meat) used was 75.5% of the carcass weight, the average of two studies[31,32].

The average slaughter liveweight for grain-based production was from the federally inspected category of the USDA Livestock Slaughter report for the time period of January–December 2010[33]. Average carcass weight was 60.3% of the average slaughter liveweight based on average cattle carcass weight divided by the average federally inspected slaughter liveweight[33]. Seventy-three percent of the carcass weight is the saleable meat (bones excluded) assuming an average of Yield Grade 3[34]. The total annual per capita beef consumption was divided by the pounds of saleable meat per animal to determine the number of animals needed to meet Michigan's consumption.

The number of broilers needed was determined for both pasture-based and confinement systems using a process similar to that described for cattle. The average slaughter liveweight of pasture-based broilers (D. Salatin, personal communication, January 1, 2010) was determined and verified with a local producer (P. Henne, personal communication, July 7, 2010) and Extension Specialist (D. Karcher, personal communication, October 2009–January 2011). The average broiler slaughter liveweight for confinement operations was determined[35]. The broiler carcass weight is on average 70% of the slaughter liveweight (D. Karcher, personal communication, October 2009–January 2011) in each production system and was used as the saleable pounds per chicken. This figure was used to determine the total number of broilers needed to meet Michigan's demand. No allowance was made for lost/diseased birds.

Table 1. Beef feedlot diets.

Ingredient	DDG diet (%)	Non-DDG diet (%)
DDG diet		
Distiller's grain with solubles	29	–
Corn silage	25	34
High moisture corn	44	60
Soybean meal	–	2
Mineral supplement with Rumensin	2	–
Protein–mineral supplement with Rumensin	–	4

Source: Dr Steven Rust Michigan State University Extension, Beef Cattle Nutrition and Management.

The number of laying hens required for egg production was determined. The average number of eggs per chicken-day in the pasture-based system was identified (D. Salatin, personal communication, January 30, 2010) and verified (D. Karcher, personal communication, October 2009–January 2011) to ensure a reasonable range for Michigan. Average number of eggs per chicken-year was then calculated. Average egg production per bird in conventional systems was determined[12]. The number of eggs consumed per year in Michigan was divided by the average annual production to determine the number of laying hens needed. No allowance was made for lost/diseased hens, egg breakage or seasonality.

Pasture and beef production

Across all species, using known feed efficiencies and animal requirements, necessary acreage allotments for pasture, hay and crops were calculated. We elected to view the production system merely for terminal production and did not incorporate any replacements or concurrent production systems including replacement production or reproductive males. For pasture-based production the land footprint of the directly grazed pasture as well as the land required to grow feed and hay was considered. The pasture acreage for the broilers and the laying hens was also determined. The land footprint of the buildings and feedlots were not included in the final calculations.

The number of cattle required each year to meet beef demand determines the number of cow–calf pairs required. General calf weaning age is assumed to be 205 days[36] with average daily dry matter requirements per cow–calf pair of 36 lbs[37]. The daily dry matter requirement per dry cow of 23 lbs[36] was used for the remaining 160 days of the year. Both beef production systems were analyzed using the same cow–calf acreage and nutritional requirements. The total requirements for the dry cows were added to the pounds of cow–calf dry matter requirement to reach a total for the cow–calf portion of the production system.

The average dry matter production of Michigan's hayfields was calculated[38] with a 13% reduction for dry matter conversion[39]. This was used to calculate total acres needed for the cow–calf and dry cow components of the system. No allowance was made for lost hay due to rain, drought or other factors. The acreage requirement for the grass-finished cattle production was based on weight gain per acre per year (D. Salatin, personal communication, January 30, 2010), with production per acre confirmed for Michigan and used to determine pounds of saleable meat per acre and total required acres. The yearly gain per acre used for the grass-finished production was 600 lbs (D. Salatin, personal communication, January 30, 2010; J. Rowntree, personal communication)[30]. The overall pasture requirement for this system was then determined by adding the acreage needed for the cow–calf system to the grass-finished total.

There are two commonly used diets in a feedlot finishing system (S. Rust, personal communication, June 16, 2011) (Table 1). One diet includes dried distillers grains (DDGs), a byproduct of corn ethanol production. It is estimated that 36% of beef producers in the upper Midwest use DDGs in their feedlot diets[40]. It was assumed that 36% of Michigan producers use DDGs in their feedlot diet and therefore 36% of the cattle were being fed a diet with DDG. This figure might be somewhat underestimated as feeding DDGs is more common in larger feedlots, thus the percentage of cattle might be higher[39]. Because the DDG-based diets require more acreage than the non-DDG diet this may underestimate total acreage needs in this system. However, the value of the ethanol produced is not accounted for in this study and it could be argued that the acreage required for the DDG diet should be discounted due to the fact that there are two uses coming from the same corn acreage. Confirmation that sufficient DDGs exist in Michigan to supply feedlot needs was determined from Michigan annual ethanol production data[41]. Nationally 42% of DDGs produced are used in feedlots[40] and it was assumed consistent for Michigan. Forty-two percent of the Michigan DDG poundage is slightly greater than the total amount needed for the DDG feedlot diet.

The average number of days in the feedlot (227 days) was established by subtracting the average entry weight[35] from the average slaughter weight[33], divided by the average weight gain per day (3 lbs d^{-1}). The pounds of feed consumed per feedlot animal was calculated and the lifetime feed consumption per animal was separated into pounds of ingredients based on diet formulations. The total tons of each feed ingredient were then calculated.

Feedlot feed consumed was divided by the average tons of Michigan production per acre to calculate total acreage requirements[42]. The overall total of the acreage needed for the feedlot finishing system was calculated by adding the cow–calf acreage requirements to the feedlot total.

Table 2. Pasture diets.

Ingredient	Laying hen (%)	Broiler (%)
Total corn	49.7	52
Soybean meal	30.8	29
Oats	10.9	11
Minerals and supplements	8.5	8

Source: Salatin, 1999.[44]

Table 3. Confinement diets.

Ingredient	Laying hen (%)	Broiler (%)
Corn	66.50	57.5
Soybean	26.50	36.5
Minerals and supplements	7	6

Source: Dr Darrin Karcher MSU Extension Poultry Specialist.

Table 4. Consumption and production data.

Product	Per capita yearly consumption[1]	Michigan yearly consumption	Number of animals required—grass based	Saleable product (lbs) per animal	Number of animals required-conventional	Saleable product (lbs) per animal
Beef	66.7 lbs yr^{-1}	659,318,000 lbs yr^{-1}	1,422,000	464	1,170,000	563
Chicken	79.6 lbs yr^{-1}	786,738,000 lbs yr^{-1}	224,782,000	3.5	187,319,000	4.2
Eggs	247.7 eggs per yr	2,448,178,000 eggs per yr	11,179,000	219 eggs per yr	8,490,000	288 eggs per yr

[1] Values for consumption of beef and chicken is boneless meat.

Broiler and egg production

The feed consumption for the pasture-based broiler production system was calculated from the broiler feed conversion ratio (2.5)[11,43] multiplied by the slaughter liveweight of the broiler (D. Salatin, personal communication, January 30, 2010) to yield the pounds of feed required per bird. The tons of individual feed ingredients were then determined based on the pasture-based broiler diet[44] and the diet confirmed by a local Michigan producer (P. Henne, personal communication, July 7, 2010).

The confinement broiler feed requirements were calculated using the same method. The average feed conversion ratio (1.9) and the average slaughter liveweight were determined[35]. Similar to the beef cattle feedlot diets, the 'average' diet for the confinement birds was determined (D. Karcher, personal communications, October 2009–January 2011). Total cropland acreage for broiler production feed was calculated analogously to that of the necessary beef feedlot diet crop production described above[41].

The pasture acreage requirements were determined using an average stocking rate of 1000 broilers per acre per year (D. Salatin, personal communication, January 30, 2010). The egg production calculation was based on feed conversion, in this case in pounds of feed per dozen eggs. The pasture-based feed conversion was calculated as the average weight of the egg (g) per total feed (g)[13]. The feed allocation was 3.4 and 3.2 lbs of feed per dozen eggs in the pastured and confinement systems, respectively[13]. This was converted to pounds of feed per dozen eggs and then to total pounds of feed required per year. The pounds of ingredients were calculated from the total feed needed based on the pasture diet percentages (Table 2). The confinement production feed conversion per dozen eggs was determined using industry average diet formulations (Table 3) (Anonymous, personal communication, January 5, 2011). From the total tons of each ingredient the required acreage was calculated as above.

The pasture requirements for the pasture-based laying hens were based on the number of layers needed to produce the eggs following the Polyface Farm strategy (D. Salatin, personal communication, January 30, 2010).

In determining the overall land requirements for the MSPR system, similar to Polyface Farms, it was determined that the broiler/egg pasture production acreage requirements would fit within the beef production so no additional acreage is allocated for these animals. The MSPR system total acreage was calculated by adding the total pasture required for producing beef, and the cropland needed to produce the feed for the broilers and laying hens. The calculation of the acreage footprint for the confinement operations was defined as the total acreage requirements needed to produce feed for each system summed.

Results

US residents on average consume 79.6 lbs of chicken, 247.7 eggs, and 61.2 lbs of beef per year[45] with upper Midwest beef as 109%[28] of the national average or 66.7 lbs yr^{-1} per person. Michigan's population is estimated at 9,883,640[29]. Table 4 illustrates total estimated consumption and animals required to fulfill this demand. This was converted into animals required in the two systems as described in the methods (Table 4).

Broiler feed conversion:gain was 2.5 versus 1.9 lbs for the pasture-based[42] and confinement systems, respectively.

The acreage needed for each production system assuming either 100 or 25% of current consumer demand met is illustrated in Table 5. The acreage requirements for pasture or for growing feed were calculated based on the

Table 5. Feed and acreage requirements[1].

	Tons of feed needed	Acreage to grow feed	Cow–calf acreage	Pasture needed	Total
Pasture					
Beef	0	0	3,541,000	2,501,000	6,140,000
Broiler	1,405,000	734,000	0	225,000	959,000
Eggs	350,000	186,000	0	932,000	1,117,000
Total acreage minus pasture for broilers and eggs (100% consumer demand)					7,059,000
Total acreage (25% of consumer demand)					1,765,000
Conventional					
Beef	4,486,000	1,353,000	2,915,000	0	4,268,000
Broiler	1,079,000	524,000	0	0	524,000
Eggs	325,404	139,000	0	0	139,000
Total acreage for production system (100% of consumer demand)					4,930,000
Total acreage (25% of consumer demand)					1,233,000

[1] Feed is presented on an 'as-fed' basis.

Table 6. Farms needed.

	Single farm production per year	Pastured animals/ eggs needed	Number of farms needed for production
Beef	400 cattle	1,422,000 cattle	3600
Broiler	30,000 broilers	224,782,000 broilers	7500
Eggs	900,000 eggs	2,448,178,000 eggs	2700

average cropland production (tons per acre) in Michigan: corn—3.35, soybean—1.16, silage corn—14.69 and oats—0.94[37,41].

Hence, the total acreage requirement for beef production at 100% demand was 4,930,000 acres for the confinement system and 7,059,000 acres for the MSPR system. At 25% of demand met the comparable acres are 1,233,000 and 1,765,000 for the confinement and MSPR systems, respectively.

The calculated number of farms of the size of Polyface Farm (approximately 1000 acres) (Table 6) required was based on their annual production (D. Salatin, personal communication, January 30, 2010)—approximately 400 cattle, 30,000 chickens and produce 900,000 eggs per year. To produce beef in the manner utilized at Polyface Farm would require approximately 3600 similar farms in Michigan; 7500 farms would be required for the broiler requirements and 2700 farms for eggs.

Discussion

The purpose of this study is to critically analyze a popularly held notion—that transforming our agrifood system to one based on a much different average scale and style of agriculture would be relatively simple and efficient given the current state of research and practice. It is not intended as an attempt to either criticize or praise either system. It has a backdrop of myriad challenges facing agriculture in the years ahead, including the cost and sources of energy, the availability of fresh water in current 'production centers' nationally[46], and the projected depletion of our mineral resources or their concentration in politically contested areas of the globe[47]. It is intended to identify the magnitude of change that would be required to simultaneously maintain our current diets and transform the production system to one based on pasture and individual farm-scale alteration. We used Michigan, USA as our study site for several reasons: first, it has a scale and scope of agriculture that encompasses all the species discussed here as well as many others; secondly, with a population of nearly 10 million it is sufficiently large to extrapolate the issues to the remainder of the country; and thirdly, it provides good boundaries to examine changes that would need to emerge from other parts of the food system and agricultural landscape for such an expanded strategy to occur. Thus, the implications in relation to the number of acres and farms needed to provide Michigan with beef, chicken and eggs using an MSPR system, underscores some of the ramifications this switch would have on other segments of the agricultural landscape. These are outside the focus of this study and will only be discussed in passing. We used the MSPR system analysis supplying all the beef, chicken and eggs for 10 million people in an attempt to systematize the issues of scaling production to a large population. The confinement/grain-based production estimate is a way to comparatively benchmark.

The analysis outlined above takes the extreme position —100% of current consumption levels from the geographic area of Michigan, USA of beef, chicken and eggs would come from production within that same geographic area—while recognizing that this is practically impossible, ecologically improbable and politically untenable. We are not advocating for a diet localized to such an extreme extent nor are we suggesting that current levels of meat consumption are sustainable as world/national populations continue to grow. Finally, we picked as a reference point for the analysis the production strategy highlighted as 'preferable' in the best-selling food book of the 21st

Table 7. Fold increase—Michigan production requirements to meet demand.

		100% demand		25% demand	
	Current MI production	Pasture-based	Confinement	Pasture-based	Confinement
Beef cattle	77,000[48]	8×	6.6×	2×	1.7×
Broilers	4,042,000[49]	56×	46×	14×	11.5×
Laying hens	9,034,000[49]	1.2×	–	–	–

century to date. We have tried to be very clear that we are not criticizing the production strategy *per se*. We seek to illuminate issues that arise when a production system conducted at a few locations is conceived of as a general strategy for the nation's food supply.

To put these findings in context we will first compare them with current production figures in the geo-political boundary of focus—Michigan. We report needing 1,422,000 grass-finished cattle or 1,170,000 grain-finished cattle to meet 10 million people's current demand for beef. An eightfold increase in grass-finished cattle and a 6.6-fold increase for grain-finished cattle compared with current production providing 100% of consumer demand and twofold or 1.7-fold to meet 25% of demand (Table 7) would be necessary to feed the population.

Broiler production would need to increase even more dramatically. A 56-fold increase in the number of pasture-raised broilers or a 46-fold increase in confinement-raised broilers would be required while a 14-fold and 11.5-fold increase for 25% of demand would be required. Laying hens would only require a 1.2-fold increase with pasture-based systems and 100% demand production while all other scenarios demonstrates sufficient in-state birds.

Beef production is the single largest driver of the acreage needs for both the grass and grain-finished production systems, with broiler and laying hen pasture needs easily fitting within the beef acreage requirements for the pasture-based system. Even with the broilers rotated for 3 years on the landscape, due to concerns of pathogens and nutrient concentration, there is a large excess of beef production pasture available.

In a place like Michigan, large changes in landscape use would need to occur for such systems to become widespread providers of meat and eggs. In 2007 there was 812,000 acres of pasture land in Michigan[50]—13.2% of the grazing acreage needed to provide 100% of the current beef consumed by 10 million people with the pasture-based system. In addition 1,160,000 acres are currently used for harvested forage[37] and 213,000 acres are in the MI Conservation Reserve Program[51]. Most of this current pasture and forage land is likely used for dairy, sheep, goats and horses. If this total pastureland were available the additional total acreage needs for the MSPR production system is 3,955,000 acres—53.4% of the acres that are currently used to produce row crops[52].

When the 920,000 acres needed for producing poultry feed grain are included, there are 2,717,000 cropland acres remaining for all other agricultural production. Overall, such a production system, while maintaining current consumption levels, would utilize 72.2% of the combined pasture, harvested forage and cropland acres in the state of Michigan. There is thus reason to question the potential of this system for producing beef, chicken and eggs for all markets beyond the current niche or recognizing that our consumption of these products (especially beef) is out-of-alignment with the land's carrying capacity.

The MSPR production system can be compared with 4,930,000 total acres required for the confinement/grain-finished system. The cow–calf portion of this production system requires 2,915,000 acres of pasture. The 2,015,000 acres needed for the production of feed for the animals would bring the usage for the confinement/grain-based system to 38% of the total cropland. If production acreage of corn for grain, corn silage and soybeans remained the same, the production of the feed would require 61, 32 and 28%, respectively of the current production acreage. Overall this system would use 50% of Michigan's combined pasture, harvested forage and cropland acres, about two-thirds that utilized in the pasture-based system.

Thus, to feed Michigan's population from internal production using either system explored herein would require a large shift in the current Michigan production profile and would monopolize all current pastureland and harvested forage land. This shift would be larger for the MSPR production system but both systems would greatly limit the capability of the state to produce other crops and raise other animal products such as pork, dairy and lamb. In some ways, then, this can be thought of as an argument against a fully localized food system within the context of current consumption patterns—neither highly intensive nor more extensive systems can feed the population without severely limiting opportunities in other areas of food production. It could, of course, also be used as an argument to modify consumption habits.

However, it could also be assumed that expanded research on MSPR systems would reduce the land use difference significantly, just as research on all commodity crops over the past several decades has dramatically increased yields and thus reduced the land requirements for a given level of production[53]. There may be gains to be had in ecosystem services in these MSPR systems that in future years may begin to make them more attractive for

broader adoption as well—such things as energy use[54] and soil erosion rates[55].

Many of these pasture-based systems, such as the one modeled here, are very complex with relatively little research to aid in their optimization. In this study, conservative estimates for production were used in order to avoid an error of optimism—allowing us to say that *at most* there would be a difference of just over 2 million acres between confinement/grain-finished and MSPR systems with a potential to shrink that difference with significant research funds geared at optimizing MSPR systems.

If we step back from a 100% localized system and examine some fraction thereof, the potential appears more feasible—for example, a 25% goal for Michigan's beef, chicken and eggs produced using MSPR systems (Table 5).

A primary goal of this study was to determine what type of shift would be required in the level of farming engaged in animal production, specifically pasture-based, for a fixed population over a specific geographic place. Given that the statistics on animal producers is somewhat general and incomplete, it is difficult to fix an extremely accurate baseline for projecting needed change—however, it is important to estimate the extent and type of a change in farmer population needed in order to gauge the implications of moving toward an MSPR-dominated production system. It is also important to recognize that most farms producing at a significant scale are specialized to a single species.

There are 7848 farms producing beef cattle in Michigan, but 95% have an inventory of less than 50 beef cattle, whereas only 21 farms have an inventory of 200 or more cattle[51]. Of these, 1481 are cattle feedlots[56]. While the overall number of farms producing beef in Michigan exceeds either of the calculated farm numbers, it is reasonable to assume that very few of these farms are the size that could be expected to expand production capacity to that modeled in this study. With almost all of the farms owning < 50 cattle in a given year, drastic on-farm changes would be required to achieve farm production levels modeled herein.

The key outcome from these data is the range of challenges for animal products produced in an MSPR system being broadly available in the marketplace—sufficient farms at appropriate scale and farmers, land transformation, financial considerations, supporting infrastructure and interest in adopting new production techniques. It is certain that at current consumption and known MSPR production levels, switching to this scale of production would monopolize most of the Michigan agricultural landscape.

The same issues arise with broiler and egg production. The number of farms currently producing broilers in Michigan (1088 farms with broilers in 2007[52]) is well short of the 7500 farms needed for pasture-based production and is still less than the 3600 farms that would be required if the broilers raised per farm were increased.

In 2007 there were 5247 farms raising laying hens[49] almost double the 2700 farms required for producing enough eggs. However, 83% of the farms were in the 1–49 hen category (and only 14 farms with hen inventories over 3200[49]). Half of the existing farms would require an increase in production to just over 4000 laying hens per farm.

Data on the number of farms in Michigan that are producing pasture-based/grass finished animal products are very scarce—eatwild.com lists 22 grass-finished beef producers, 16 broiler producers and 12 farms producing eggs in Michigan. Some of the farms counted in this study produced two or three of these products and thus are counted twice. This is probably not an exhaustive list and does not profile the amount of production per farm, but it provides a sense of the scale of farms in the state attempting a similar production system.

Another indication of the number of people using grass to produce animal products shows that in 2007 there were 7151 farms that used rotational grazing[57]. This figure is fairly vague because rotational grazing can cover a wide range of management practices and probably includes a number of dairy farms using some form of grazing.

It is finally important to recognize that current consumption levels exceed the federal guidelines for protein consumption[58]. If the per capita consumption was reduced to federal nutrition guidelines, this would reduce consumption of beef, chicken and eggs by about 25%.

The cow–calf portion of the grain-finished system contributed more than half of the total acreage requirements for the confinement/grain-finished system. In the MSPR system, the production of beef was by far the largest contributor to acreage needs. There are promising signs that if the grazing systems are intensively managed there could be an increase in per acre production from the estimate used for beef cattle in this study. While not investigated thoroughly, anecdotal and preliminary data have shown the potential to reduce overall land use in these systems. For instance, high levels of applied nitrogen combined with irrigation can return 1000lbs of gain per acre[59]. New management is ever-evolving that increases pasture utilization without nitrogen inputs as well. Management-intensive grazing combined with managing swards for 30% legumes has proved to be highly productive[60]. Rouquette and Smith[61], reported that legume biological N fixation can be as high as 180lb N per acre. This advantage in pasture-based agriculture will be important given the current pressures on energy and feed.

The poultry systems are not as much of a concern, because overall they do not have large acreage requirements. Their impact is also tempered by their ability to be rotated onto land that is used for beef grass-finishing, which results in the pasture required for the broilers and

laying hens not contributing to the overall acreage totals beyond feed.

These results also indicate that the template of Polyface farm would be a very large land footprint compared with an average size for beef, broiler and egg production in Michigan. Many of the small farms would need to greatly expand in scale (and probably scope of products). Another option would be to have farms that required smaller land footprints, but it is unclear how small these farms can be while still maintaining profitability, enhancing efficiency and producing adequate products for the region.

Conclusion

This study was intended to identify the scope of change required if pasture-based systems—specifically a MSPR production system—were to supply the current beef, chicken and egg demands for a population of nearly 10 million. Clearly, this would drastically alter the current agricultural landscape. This comparison illustrates the major reason that MSPR system requires more total land than the current production system. This research also suggests a need for extensive research into optimizing these systems.

We have attempted to develop the boundary conditions, in land and farms required, in order to have these MSPR products available to the general population on a daily basis. It fills a gap in the scientific knowledge where MSPR systems have not been fully examined. Using the extreme case, where this system produces all the beef, chicken and eggs for a large population, has exposed current system limitations as well as identifying a range of beneficial research areas.

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Book Review

The Essentials of Economic Sustainability. By John Ikerd. 2012. Kumarian Press, Sterling, Virginia. 150 p. $21.95, ISBN 978-1-56549-516-6, paperback.

Essentials of Economic Sustainability is the latest challenging statement on innovative economic philosophy from an alternative opinion leader John Ikerd, retired agricultural economist from University of Missouri, Columbia. His perspective is that accelerating changes surrounding us require more than small adaptations, but rather a thoughtful reconsideration of basic principles about how the world works and our role in this dynamic reality. Ikerd paraphrases the challenge of the 1988 Brundtland Report of the UN that we must design strategies 'to meet the economic needs of the present without diminishing economic opportunities for the future' (p. 1). To fail to meet this challenge is to court instability and political volatility in the short term and to sacrifice long-term sustainability.

Unlike conventional economic thinking that begins with labor, land and capital, Ikerd's focus initially is on energy, and specifically on renewable resources and capture of solar energy and its efficient transformation to sustain human life and the biosphere. He extends the concept of conventional physical energy to meet human needs to an essential corollary of social energy, that which is 'expended in maintaining positive, productive, human relationships' (p. 3). Ikerd further describes a dimension beyond the economic and social realms to what he distinguishes as ethical relationships whose value may be deferred to the future, even while they guide decisions today.

The author describes the 'tragedy of the commons' as the lack of incentive for individuals and single corporations to preserve or protect the collective resources of the overall economy. Closely related is a tragedy of short-term profits, the stated goal of dominant corporations in the global economy that are not rewarded for long-term gains. The real challenge to charting a course to long-term sustainability is to balance short- and long-term returns, economic and social goals, and ethical and moral dimensions that often are not rewarded in conventional economic systems.

Dr Ikerd invokes the ecological principle of organizational hierarchy to describe levels of ethical, social and individual intentionality. Smaller scale components of a biological system are studied to determine mechanisms and higher level components are examined to understand meaning; in parallel he uses this concept to describe individual and group dynamics as important to establishing possibilities while higher level laws, constitutions and regulations define the boundaries recognized by society and government. For those of us versed in the ecology of natural or agro-ecosystems, this is a difficult stretch, but one that challenges our capacity to keep up with the creative thinking of the author. At the very least it is an unusual trip for us to explore this interface between agriculture and economics in an entirely new way, and at the most it is a conceptual journey we should welcome as disciplinary scientists to break out of our narrow thinking and seek better understanding of complex relationships.

The book proceeds to explore specific ecological principles and how they relate to sustainability in an economic sense, another stretch that may prove challenging to the conventional economist. In the author's view of ecological economics, most important are natural laws that inform science, especially biology and physics. The interconnectedness of all living things (holism) and their dependence on the abiotic environment defy easy understanding if we insist on observing the world through the lens of any single academic discipline. Diversity allows adaptation to changing conditions, and current rates of species extinction are far above what is essential for system resilience, a reality that is totally absent from neoclassical economic analysis. Dr Ikerd extends the importance of diversity to describe healthy social relationships, a factor that 'adds strength and durability to human relationships by increasing their resilience and regenerative capacity' (p. 35). Again, the author's uncanny ability to apply ecological terms and functions to the social and economic arena comes through.

Human societies are important for reasons more complex than those of lower animals, in contrast to ants that form colonies mostly for survival and regeneration, and we recognize such unique core values as 'honesty, fairness, responsibility, respect, and compassion' (p. 41). One could challenge the author's rather absolute interpretation of these as 'universal truths', since their definitions and applications are strongly tied to different cultures around the globe. However, less debatable are the importance attached to trust, to kindness, to courage and to individuality, and how these contribute to social relationships. Dr Ikerd describes how the current industrial and globalized network of multinational corporations attempts to achieve short-term economic interests by ignoring or diminishing importance of social relationships, except as they help a company to gain greater financial advantage. He further condemns 'contemporary

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economists [who] deny the existence of ethical values; to them all human relationships are instrumental or a means to some purely economic or personal end' (p. 48).

The book then explores definitions and the quest for economic sustainability, one that incorporates individuality along with organization and service to society. Dr Ikerd describes scarcity, demand, supply and efficiency in terms accessible to economist and agronomist alike, and why a degree of food and economic sovereignty is important at the local and national levels. Consistent with the theme of ecological description of societies, he defines 'economies as living systems' in that they should be seen as holistic, dynamic, individualistic and site-specific, and purposeful human activity systems. He expands the simplistic terms used by environmentalists that urge us to 'reduce, reuse, and recycle' materials to a higher order description of economic systems that must have the capacity to continually 'renew, reproduce, and re-organize', a close parallel to the capabilities of natural systems to adapt to changing circumstances in order to maintain a degree of stability and resilience. This leads to a conclusion that economic sustainability will not be possible without substantial redesign of the current system. Those who design future systems must consider the long term, the realities of resource scarcity, and the changing climate that causes us to explore new ways of framing questions and seeking answers. Einstein said that *Problems* [of the future] *cannot be solved by the same level of thinking that created them* [many available sources].

Dr Ikerd continues with speculation on the role of markets and the functions of governments and regulations in shaping sustainability of future economies. Of special note is his insistence that we must find accounting methods that internalize those costs that are conventionally externalized in economic analysis. Regulating international trade in ways that benefit all participants, seeking organizational methods that place equity among the highest of goals, and finding controls over such contemporary challenges as massive land grabs and other exploitation by those with cash resources are among the challenges we face in using ecology to inform the structure of international economic relationships.

The author concludes with a chapter that presents a challenge to the oxymoron of 'sustainable growth' ... a well-worn term and superficial goal that does not reflect energy, biological or ecological reality. Nearly heretical concepts such as 'steady state economies', national decisions based on pursuit of 'happiness and quality of life', 'prosperity without growth' that is defined in more complex terms than economic, and long-term equity of opportunity for people of all countries are among the building blocks of this new global economy. Certain to be challenged by those imbedded in the current economic paradigm, Dr John Ikerd perseveres in his quest for the truth and continually explores innovative ways to articulate his message to the educated public. Let us hope that his messages can penetrate the disciplinary earplugs and blinders that constrain much of our thinking in development of future agricultural, food and economic systems.

Charles Francis, University of Nebraska – Lincoln
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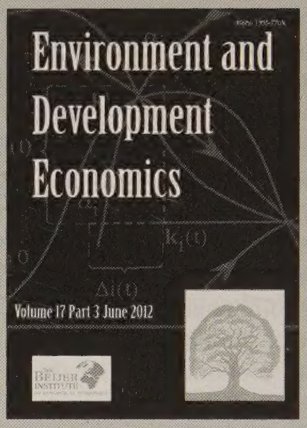

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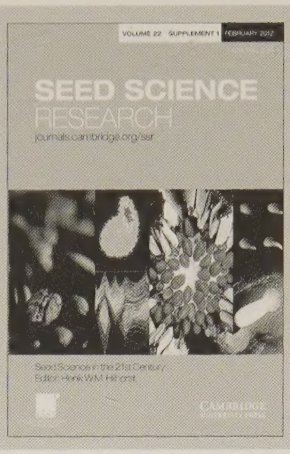

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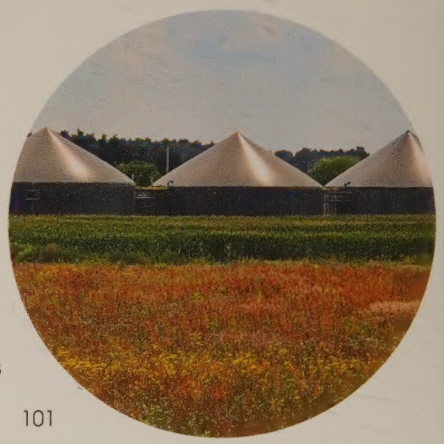

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